MAKING RECYLING ECONOMIC –

THE SUSTAINABILITY OF MATERIALS FOR THE BUILT ENVIRONMENT

Abstract

Our interaction with our planet earth is described as the techno-process which is the process of taking resources, manipulating them as required (modifying substances), making something with them, using what is made and then throwing what has been made that no longer has utility[i] away. The techno-process of take, manipulate, make, use and waste is discussed particularly in relation to reducing, reusing and recycling materials, earth systems, the web of life and materials in the built environment which, at over 70% of all materials flows, comprise the major component of the flow through the techno process. The most significant material flow is that of concrete as over two tonnes are produced per person on the planet per annum. The use of new calcium magnesium blended cements (TecEco cements) invented by the author that utilise wastes and sequester carbon dioxide is discussed as an example of the significant impact changes in materials could make.

Reducing, re-using and recycling materials would reduce the impact of the techno process on the planet, but is currently undertaken more for “feel good” political reasons than sound economic reasons in many instances. Some unique practical solutions are offered to resolve this dilemma including a unique electronic identification system for materials and the use of new generation TecEco cement composite materials as potential repositories of wastes including CO_2.

Keywords: Abatement, sustainable, sustainability, sequestration, CO_2, brucite ($Mg(OH)_2$), durability, reactive magnesium oxide, materials, magnesian, magnesia, reactive magnesia (MgO), magnesite ($MgCO_3$), hydromagnesite ($Mg_5(CO_3)4(OH)_2 \cdot 4H_2O$), fly ash, pozzolan, hydraulic cement, Portland cement, concrete, process energy, embodied energy, lifetime energy, durability, shrinkage, cracking, extract, extraction, permeability, rheology, emissions, flow, matter, materials, substances, wastes, reduce, reducing, reuse, re-using, recycle, recycling, take, manipulate, use, waste, utility, digital, silicon chip.

A John W Harrison, B.Sc. B.Ec. FCPA.

John Harrison is managing director and chairman of TecEco Pty. Ltd. and best known for the invention of tec, eco and enviro-cements known mainly for their impact on sustainability. John is an authority on sustainable materials for the built environment and was a founder of the Association for the Advancement of Sustainable Materials in Construction.

The Impact of Population Growth, Technology and Consumption

There is not the room in this paper to go into the detail of our legacy on this planet. Suffice to say we have taken over, we control the world and our impact has been very detrimental to virtually all earth systems.

Our detrimental linkages with the environment have grown due to population increases and partly due to shifts in the technological basis of the techno – process whereby we take resources from the environment, manipulate the molecules, make something, use it and then when we have finished it waste it.

According to the American Association for the Advancement of Science Population and Environment Atlas[ii], “Consumption and technology impact on the environment by way of two major types of human activity.

First, we use resources. We occupy or pre-empt the use of space, and so modify or remove entirely the habitats of many wild species. We extract or take resources -- growing food, catching fish, mining minerals, pumping groundwater or oil. This affects the stock of resources available for humans and for other species in the future.

Second, we dump wastes -- not just those that consumers throw away, but all the waste solids, liquids and gases that are generated from raw material to final product. These affect the state of land, groundwater, rivers, oceans, atmosphere and climate.”

If we want to survive the next millennia as a race we will need to take more responsibility for the environment.

The Techno-process

Our interaction with the geosphere-biosphere[iii,iv] is described as the techno-process which is the process of extracting resources, manipulating them as required (modifying substances), making something with them, using what is made and then throwing what has been made that no longer has utility[v] away.

The techno-function (Take⟶Manipulate⟶Make⟶Use⟶Waste) describes this techno – process.

The impact of the techno - function on the planet is significant. Resources are not unlimited and the planet does not have an infinite capacity to reabsorb wastes.

To reduce linkages with the environment and for our own long term sustainable survival the take and waste need to be reduced and preferably eliminated to what is renewable and preferably biodegradable. To do this we must adopt the philosophy of Reducing, Re-using, Recycling and Recovering.

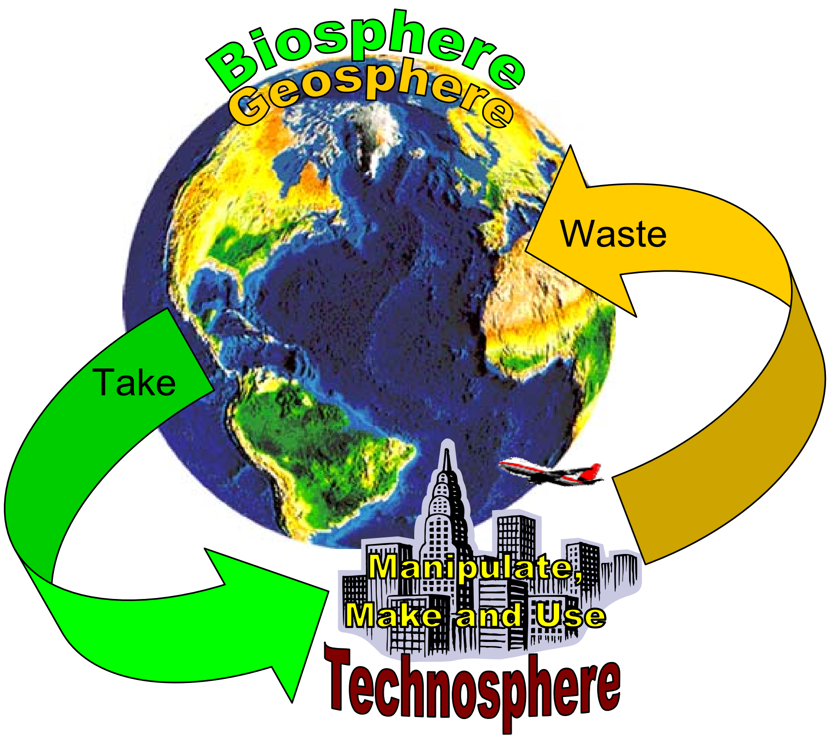
Resources extracted from the geosphere-biosphere can be classified broadly into several non exclusive types. Resources are renewable or non renewable, short use or longer use materials.

- Renewable Resources

  A renewable resource is any natural resource (such as wood or solar energy) that can be replenished naturally[vi] with the passage of time. Can be either short use (renewable energy) or long use (wood). Depend on the health of the geosphere-biosphere for natural replenishment.

- Non-Renewable Resources

  The use of non-renewable resources as materials or energy sources leads to depletion of the Earth's reserves. Non renewable resources are characterised as non-renewable in human relevant periods.



For sustainability the extraction of resources and production of waste need to be reduced and preferably limited to the extraction of resources that are renewable and production of wastes that are biodegradable

Figure 1 –The Techno - Process.

- Short Use Resources

  Are renewable (food) or non renewable (fossil fuels). Have short use, are generally extracted modified and consumed, may (food, air, fuels) or may not (water) change chemically but are generally altered or contaminated on return back to the geosphere-biosphere (e.g. food consumed ends up as sewerage, water used is contaminated on return.)

- Long Term Use Resources or Materials

  Materials are "the substance or substances out of which a thing is or can be made[vii]." Alternatively they could be viewed as "the substance of which a thing is made or composed, component or constituent matter.[viii]"

> Some materials are renewable (wood), however most are not renewable unless totally recycled (metals, most plastics etc.) Materials generally have a longer cycle from extraction to return, remaining in the techno-sphere[ix] whilst being used and before eventually being wasted. Materials may (plastics) or may not (wood) be chemically altered and are further divided into organic (e.g. wood & paper) and inorganic (e.g. metals minerals etc.)

Other classifications are possible such as surface or sub surface resources, etc. but not relevant to my arguments in this paper.

The techno-process is very inefficient in that large quantities of renewable and non renewable resources are extracted to produce small quantities of materials which themselves are used to produce even smaller volumes of things actually used, many of which do not retain utility (value to us) very long before they are in turn discarded.

"Studies show that between a half and three-fourths of the materials used in our industrial economy are generated and treated as waste before ever entering the economy. They are not seen or treated as commodities and aren't valued as such[x]".

It is essential that we find more uses for these wastes for linkages to the biosphere-geosphere to be reduced. The inventive is that economically we would be better off.

Earth Systems

The Earth has well-connected systems. Carbon dioxide emitted in one country is rapidly mixed throughout the atmosphere, and pollutants released into the ocean in one location are transported to distant parts of the planet. Local and regional emissions create global environmental problems.

It is difficult to completely understand let alone put numbers to the complex flows and balances that go on around the planet. We do know however that pollution from wastes of various kinds has affected atmospheric composition, land cover, marine ecosystems, coastal zones, freshwater systems, global biological diversity and many other global systems.

Due to our pervading interference the constituent components of matter which are molecules are no longer produced or used in equilibrium. Of particular concern and therefore the most studied is the carbon cycle which is out of balance. Complex carbon based molecules put together by living matter over many millions of years are being used as if there was no tomorrow. The level of carbon dioxide waste from this process is rising too rapidly for conversion by photosynthesis or utilization by organisms for skeletons and shells. As a consequence the level of CO_2 in the air has risen from 280 parts per million in pre-industrial times to around 370 parts per million today. Methane concentrations have also risen by 145 percent over the same period. Before the industrial revolution gaseous chlorines did not exist in the atmosphere. By 1996 there were 2 731 parts per trillion, most of these produced in the 20th century[xi].

Rising atmospheric carbon dioxide concentration and its potential impact on future climate is an issue of global economic and political significance. Of possible even greater importance is the depletion of oxygen in the atmosphere.

A study of all the other earth systems including for example the hydrosphere of which freshwater systems are a part and in relation to which water quality, salinity and supply are major issues or sea fisheries which are in major decline is beyond the scope of this paper.

The Affect of the Techno-Process on the Web of Life

Figure 2 – Most Pollution Eventually Makes it to our Waterways Killing Fish and other Life[xii]

What distinguishes our planet from any other we have yet discovered is that there exists life, comprising carbon based molecules which have evolved in a delicate balance with the rest of the atoms and molecules that make up planet earth.

Living matter is different from dead matter in that it contains genetic coding and has the ability to take atoms and molecules from the environment to build new replicates of itself for the future. This delicate balance is characterized by the flow of substances from the dead world to living matter and in reverse and has gone on for billions of years. Since the dawn of mankind and in particular the industrial revolution our ability and willingness to manipulate everything around us has however has wreaked havoc with living life forms.

For example, according to some estimates, seventy percent of Earth's coral reefs will cease to exist in the next forty years if the current trend continues. Every year, around one thousand (1,000) species are driven to extinction. The loss of tropical forests is especially alarming as they are the home habitat of over fifty percent of the world's species of plants and animals [xiii].

There is no doubt that we have seriously disturbing the "web of life" and evidence is mounting of worse future problems unless we can reduce our impact.

We take atoms and molecules from the dead and living matter around us in what is the techno-process and then when finished throw them "away". There is no such place as "away" Many of these transformed atoms and molecules enter the global commons and return as part of the flow negatively affecting our wellbeing and that of other living organisms on the planet.

Persistent chemicals are not confined to the area in which they are created. Gases like Chloro fluoro hydrocarbons (CFC's) which is a waste enter what is the global commons.

CFC's were developed during the 1930s and found widespread application after World War II. They are halogenated hydrocarbons, mostly trichlorofluoromethane and dichlorodifluoromethane and were used extensively as aerosol-spray propellants, refrigerants, solvents, and foam-blowing agents because they were non-toxic and non-flammable and readily converted from a liquid to a gas and vice versa.

CFCs were however found to pose a serious environmental threat because in the stratosphere they broke down under ultraviolet light releasing chlorine which destroyed ozone. A hole over Antarctica developed in the ozone layer which shields living organisms on earth from the harmful effects of the sun's ultraviolet radiation.

"Because of a growing concern over stratospheric ozone depletion and its attendant dangers, a ban was imposed on the use of CFCs in aerosol-spray dispensers in the late 1970s by the United States, Canada, and the Scandinavian countries. In 1990, 93 nations agreed to end production of ozone-depleting chemicals by the end of the century, and in 1992 most of those same countries agreed to end their production of CFCs by 1996[xiv]."

Heavy metals have been of particular concern. The term "heavy metal" refers to metals that are relatively high in density and toxic or poisonous even at low concentrations. Examples include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb).

Heavy metals are natural components of the Earth's crust and cannot be degraded or destroyed. They are particularly dangerous when released as wastes because they tend to bio-accumulate up the food chain.

For example, marine organisms can consume a particularly dangerous form of mercury called methylmercury. When fish eat these organisms, the methylmercury is not excreted, but retained in bodily tissues. The older the fish and the more organisms further down the food chain they have consumed, the greater the amount of methylmercury in their tissues. The accumulated methylmercury is concentrated as it is passed up the food chain and any organism at the top such as us faces a serious risk of mercury poisoning by eating such fish.

Heavy metals can enter a water supply from industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater. We are constantly being alerted to the fact that living organisms in the far reaches of the globe contain significant traces of organic and metallic pollutants and that the deepest marine sediments, remotest glaciers and icecaps are contaminated. The list of contaminants is frightening and long. Pollution from waste is everybody's problem.

The Environmental Affects of Resource Extraction in the Techno – function

Take→Manipulate→Make→Use→**Waste**

Detrimental Affects on
Earth Systems

In the past the main cause of concern was that resources would not be sufficient to sustain the human race let alone the techno-process (even if it was not called that) "Frequent warnings were issued that we faced massive famines, or that we would "run out" of essential fuels and minerals.[xv]"

Renewable resources such as water, fish stocks, even the air we breathe are today of much greater concern because they are now understood to be much more fragile and influenced strongly by overuse and pollution

According to the recent report "Global Change and the Earth System - A Planet under Pressure" IGBP SCIENCE No. 4[xvi], funded largely by the Swedish Government, our planet is changing quickly. In recent decades many environmental indicators have moved outside the range in which they have varied for the past half-million years. We are altering our life support system and potentially pushing the planet into a far less hospitable state.

It is not population growth per say that is the problem; it is the increase in flows through the techno-process previously defined associated with increasing levels of the technology factor and associated consumption.

Exponential Growth

There is an explosion of substances through the techno-process many of which have damaging wastes associated with them. The worst are fossil fuels and cement production.

The Industrial Revolution was the beginning of the transformation of societies into the energy-intensive economies of today. The consumption of fossil fuels has had a big impact on atmospheric composition.

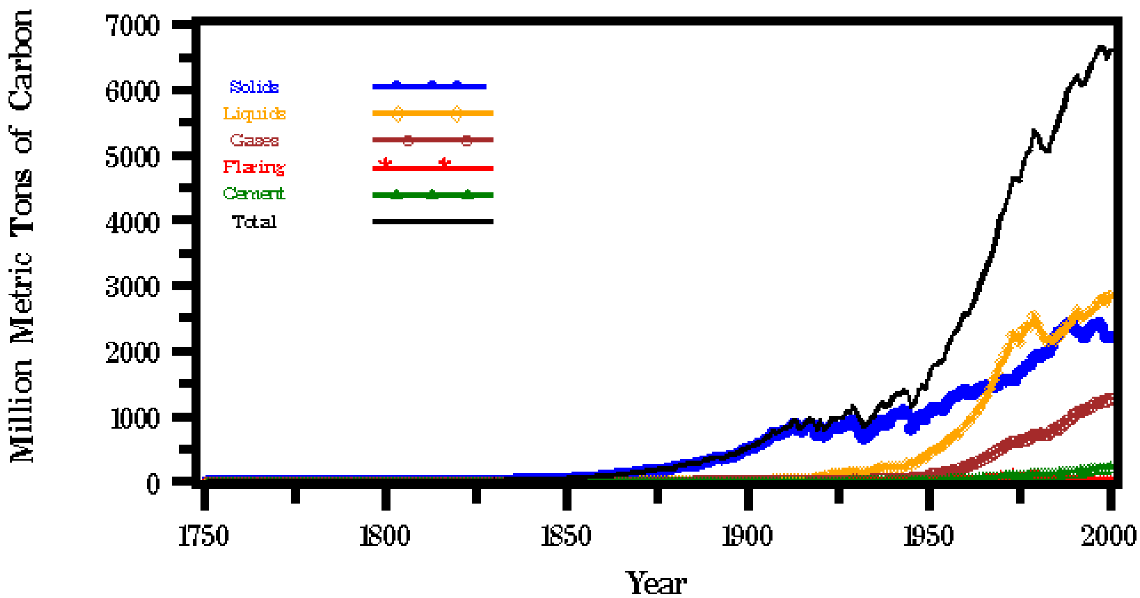
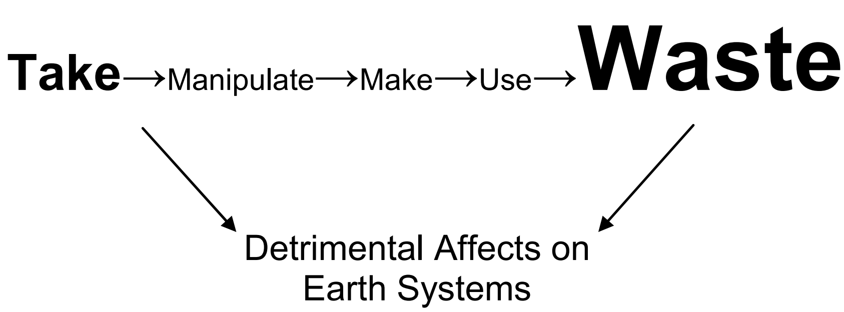


Figure 3 - Global CO_2 Emissions from Fossil Fuel Burning, Cement Production, and Gas Flaring for 1751-2000.[xvii]

Another major source of emission is the production of cement. In 2003 the world produced 1.86 billion tons of cement[xviii] -- about a quarter of a ton for every man, woman and child on Earth. Production is now probably well over 2 billion tonnes. Over 13 billion tonnes of concrete are the result which is over two tonnes per person per annum on the planet.

The growth of energy consumption is closely correlated with the increases in gross national product which is a measure of economic development. The current consumption patterns of fossil fuels, as well as contributing to emissions, is not sustainable and neither is the production of cement (See Reducing the Impact of the Techno Process on page 9.) The emissions from the burning of fossil fuels and production of cement are shown in Figure 3.

The Environmental Affects of Wastes in the Techno-function



Of major concern is the problem of wastes which are the output of the techno function according to which wastes are created in producing and consuming resources.

Huge volumes are produced. In the mid-1990s for example countries belonging to the OECD produced 1.5 billion tons of industrial waste and 579 million tons of municipal waste -- an annual total of almost 2 tons of waste for every person[ii].

The figures for building materials in waste streams vary around the globe and one of the problems is that the method in which audits are conducted also varies making it hard to obtain comparative statistics.

According to Maria Atkinson of the Green Building Council of Australia the figure nationally of waste going to landfill from construction and deconstruction activities (predominantly the churn of refurbishments) was around 40%[xix].

The flow of unwanted or waste materials is affecting our planet. The solid wastes that are not incinerated generally go to landfill and pollute water courses and the local area. Liquid and gaseous pollutants are more insidious and spread invisibly in the global commons.

Landfill is the technical term for filling large holes in the ground with waste. These holes may be specially excavated for the purpose, may be old quarries, mine shafts and even railway cuttings. More recently the mountains or islands made of waste are being created.

Apart from wasting what are potentially resources landfill sites produce climate changing gases such as methane which is some 25 times more powerful than CO_2 as a greenhouse gas but only remains in the atmosphere for about ten years and so looses it's greenhouse effect quickly compared to CO_2 which remains in the atmosphere significantly longer.

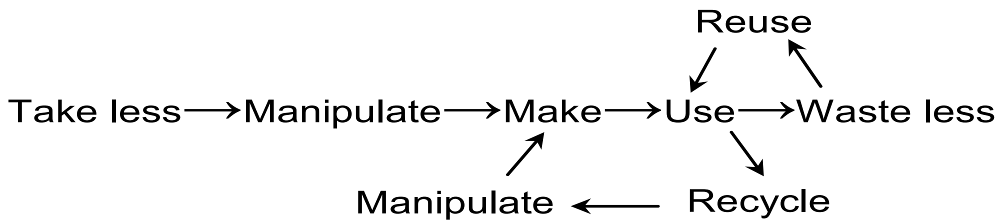
The current atmospheric concentration of methane is 1.8 ppm or 25x1.8 = 45 ppm CO_2 equivalent. This is 12% of CO_2 concentration and its growing 2.5 times as fast[xx]. The current concentration of CO_2 on the other hand is around 370 ppm.

Landfill can cause ill health in the area, lead to the contamination of land, underground water, streams and coastal waters and gives rise to various nuisances including increased traffic, noise, odours, smoke, dust, litter and pests.

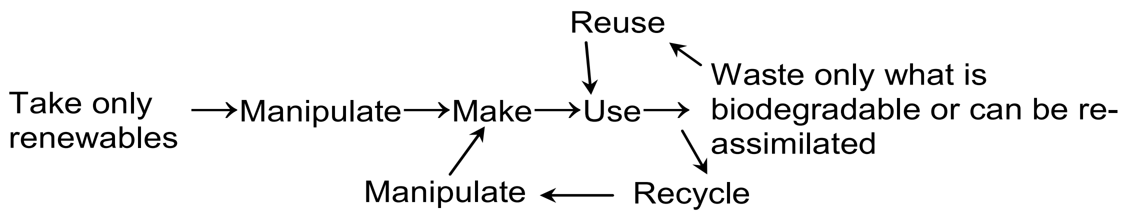
According to the EPA “Resources that simply become waste are not available for future generations and extraction and harvesting of additional resources can have long term environmental impacts. Even as we implement protective waste management programs, toxic chemicals still can find their way into the environment throughout the life cycle of materials in extraction, production, transportation, use, and reuse. Persistent, bio accumulative and toxic chemicals released into the environment can present long term risks to human health and the environment, even when released in small quantities.[xxi]”

Reducing the Impact of the Techno Process

It is essential that the human race, with all the power it has over the environment moves rapidly towards reducing the linkages between the techno-sphere and the geosphere-biosphere before it is too late. To do this the inputs and outputs of the techno-function need to be reduced. We need to change the techno function to:



And more desirably to:



To make a material difference to the quantum of resources extracted and consequent and subsequent waste we need to tackle the big problems first and the biggest problem is the weather. So far “everybody is talking about the weather but nobody does anything about it[xxii]” Now is the time for focussed action to modify the principal techno sub processes that pollute with carbon dioxide.

Fossil Fuels

Energy consumption results in the most gaseous releases because of our dependence on fossil fuels. There is a strong need to kick the fossil fuel habit however this is unlikely to happen unless alternative sources of energy become more economical. “This may be sooner than we think as “just under half of the world’s total endowment of oil and gas has been extracted already, and that output will begin to decline within the next five years, pushing prices up sharply.[xxiii]” Most geologist however concur that thirty rather than five years is more likely.

Even if we do kick the fossil fuel habit before it kicks us, it will take centuries to bring the carbon balance back down to levels in the 50’s. Abatement and sequestration on a massive scale are essential. “Complementary to traditional areas of energy research, such as improving energy efficiency or shifting to renewable or nuclear energy sources, carbon sequestration will allow continued use of fossil energy, buying decades of time needed for transitioning into less carbon-intensive and more energy-efficient methods for generating energy in the future.[xxiv]”

It is encouraging that there is a slow shift to renewable energy as Figure 4 shows.

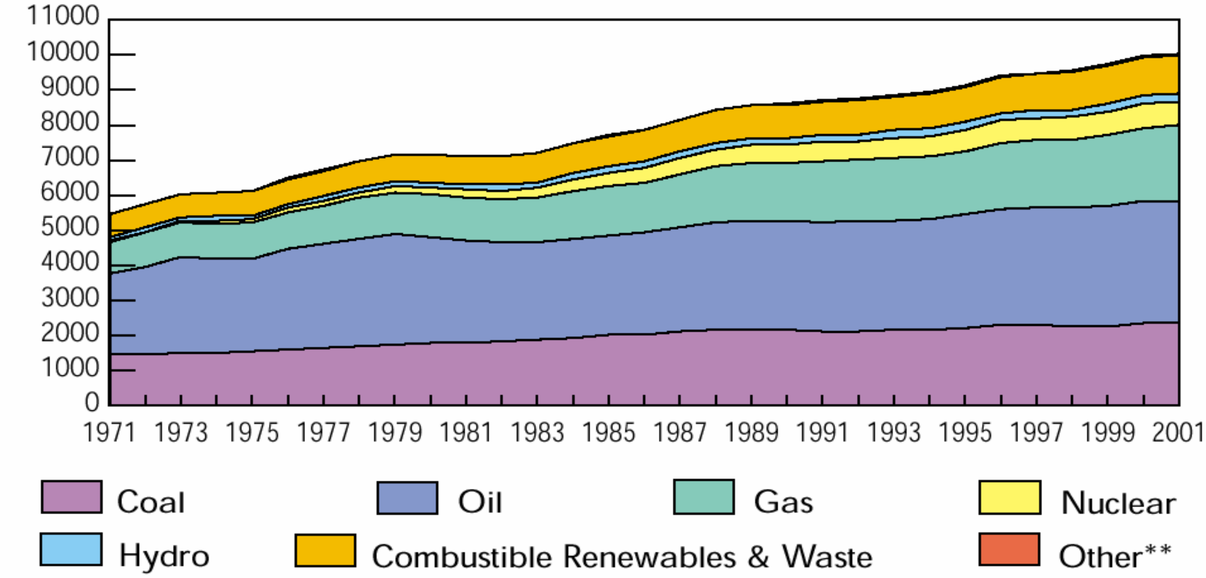


Figure 4 - Evolution from 1971 to 2001 of World Total Primary Energy Supply[xxv]

Cement and Concrete

The main material used for buildings and infrastructure is concrete. Concrete is made by utilising a cement such as Portland cement to bond stone and sand together. Ordinary Portland Cement (OPC) is the most common cement used and the concrete made with it is an ideal construction material, as it is generally economic, durable, easily handled and readily available.

Contrary to lay understanding Portland cement concretes have low embodied energies compared to other building materials such as aluminium and steel, have relatively high thermal capacity and are therefore relatively environmentally friendly.

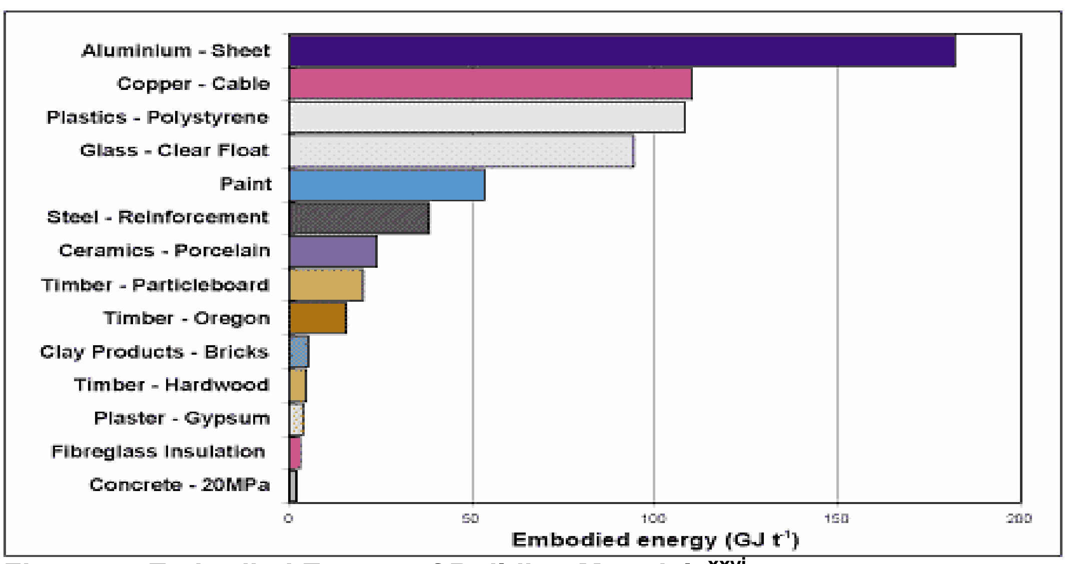


Figure 5 - Embodied Energy of Building Materials[xxvi]

However concrete, based mainly on Portland cement clinker, is the most widely used material on Earth. Production for the year ended 30 June 2003 was 1.86 billion tonnes[xviii], enough to produce over 7 cubic km of concrete per year or over two tonnes or one cubic metre per person on the planet resulting in significant global emissions.

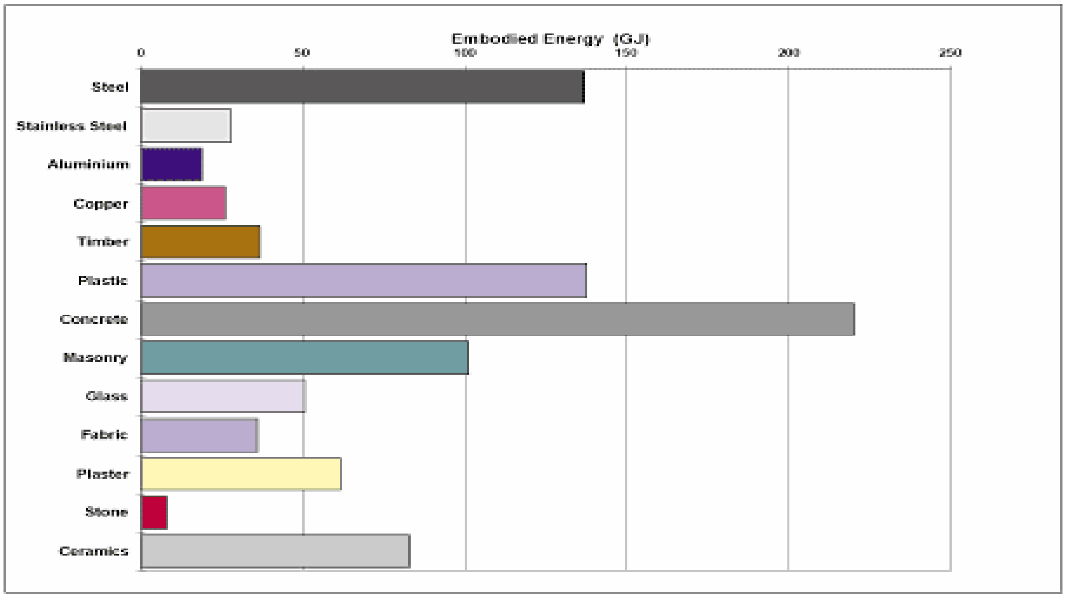


Figure 6 - Embodied Energy in Buildings[xxvi]

As a consequence of the huge volume of Portland cement manufactured, considerable energy is consumed (See Figure 6 - Embodied Energy in Buildings[xxvi] on page 12) resulting in carbon dioxide emissions. Carbon dioxide is also released chemically from the calcination of limestone used in the manufacturing process.

Various figures are given in the literature for the intensity of carbon emission with Portland cement production and these range from 0.74 tonnes coal/ tonne cement [xxvii] to as high as 1.24 tonne [xxviii] and 1.30 tonne.[xxix] The figure of one tonne of carbon dioxide for every tonne of Portland cement manufactured[xxx] given by New Scientist Magazine is generally accepted.

The production of cement has increased significantly since the end of World War II.

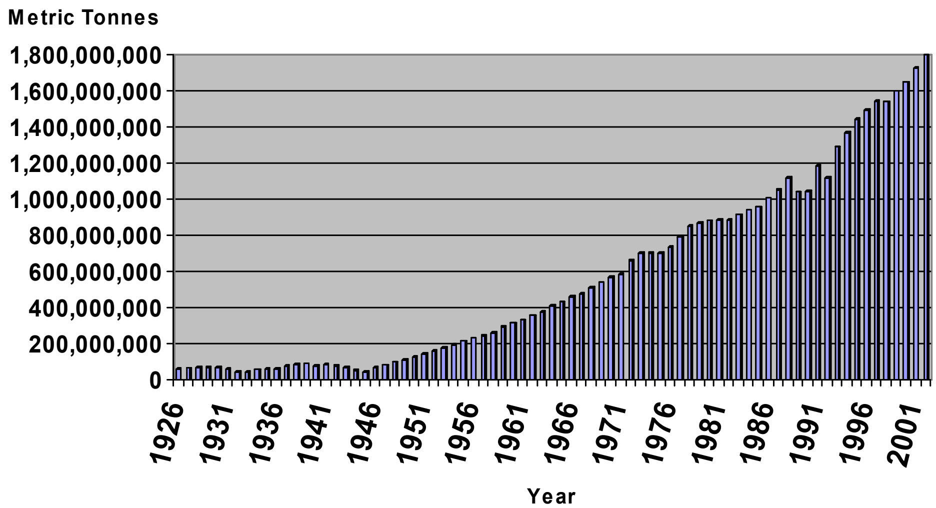


Table 1 - Cement Production = Carbon Dioxide Emissions from Cement Production 1926-2002[xxxi]

These releases are due to:

- The burning of fossil fuels in the kilns used;
- Emissions associated with electricity used during the manufacturing process, and;
- The chemical release of CO_2 from calcining limestone.

As of 2004 some 2.00 billion tonnes of Portland Cement (OPC) were produced globally[xxxii]. This accounts for more embodied energy than any other material in the construction sector[xxxiii]. The manufacture of OPC is one the biggest single contributors to the greenhouse effect, accounting for between 5%[xxxiv] and 10%[xxxv,xxxvi] of global anthropogenic[xxxvii] CO_2 emissions.

Global production of cement is likely to increase significantly over the coming decades as:

- Global population grows;
- GDP grows;
- Urban development continues; and,
- Through increasing industrialisation.

A direct consequence of such huge usage and growing demand is the associated enormous potential for environmental benefits and improvements in sustainability.

Summary

The key to more rapid moves toward sustainability is to change the technology paradigm and this is discussed in more detail later in this paper (See Making Reducing, Re-using and Recycling Work in the Long Term without Subsidies or Taxes On page 18). If solar cells for example suddenly became very cheap to make a far higher proportion of electricity would be generated using them.

The Built Environment - A Focus for Sustainability Efforts

Our understanding of the flows and interactions in the global commons is very inadequate. The widely held view is that sustainable management strategies are complex to devise and politically difficult to introduce. What if they were economic?

The obvious place that seems to have been missed by just about everybody to focus sustainability efforts is the built environment. It is our footprint on the globe. Given the size of the built environment there are huge opportunities for changing the techno function.

The dominant proportion of what we take, manipulate and make that we do not consume immediately goes into the materials with which we build the techno-sphere. Buildings and infrastructure are our footprint on the globe and probably account for around 70% of all materials flows and of this "Buildings account for 40 percent of the materials and about a third of the energy consumed by the world economy. Combined with eco-city design principles, green building technologies therefore have the potential to make an enormous contribution to a required 50% reduction in the energy and material intensity of consumption in the post-modern world.[xxxviii]"

"In 1999, construction activities contributed over 35% of total global CO_2 emissions - more than any other industrial activity. Mitigating and reducing the impacts contributed by these activities is a significant challenge for urban planners, designers, architects and the construction industry, especially in the context of population and urban growth, and the associated requirement for houses, offices, shops, factories and roads[xxxix]."

According to the Human Settlements Theme Report, State of the Environment Australia 2001[xl], "Carbon dioxide (CO_2) emissions are highly correlated with the energy consumed in manufacturing building materials. "On average, 0.098 tonnes of CO_2 are produced per gigajoule of embodied energy of materials used in construction. The energy embodied in the existing building stock in Australia is equivalent to approximately 10 years of the total energy consumption for the entire nation. Choices of materials and design principles have a significant impact on the energy required to construct a building. However, this energy content of materials has been little considered in design until recently, despite such impacts being recognized for over 20 years."

To date the main practical emphasis has been on designing building with low lifetime energies. Little effort has been made to reduce the impact of materials on lifetime energies, embodied energies and emissions.

What Governments are doing to Encourage Sustainability

For sustainability the take and waste components of the techno-process need to be reduced and preferably eliminated to what is renewable and preferably biodegradable.

Governments generally view sustainability as a desirable goal and various policy options are being experimented with such as:

1. **Research and Development Funding Priorities**.
2. Procurement policies.

Government in Australia is more than 1/3 of the economy and can strongly influence change through:

- Life cycle purchasing policy.
- Funding of public projects and housing linked to sustainability such as **recycling**.

3. Intervention Policies.
    - Building codes including mandatory adoption of performance specification.
    - Requiring the recognition and **accounting for externalities**
    - **Extended producer responsibility (EPR) legislation**
    - Mandatory use of minimum standard materials that are more sustainable
    - Mandatory eco-labelling
4. Taxation and Incentive Policies
    - Direct or indirect taxes, bonuses or rebates to discourage/encourage sustainable construction etc.
    - A national system of carbon taxes.
    - An international system of carbon trading.
5. Sustainability Education

Consider building codes, research and development funding and policies of encouraging recycling and legislating for extended user responsibility as they are most relevant to the materials theme of this paper.

Building Codes

The emphasis has been on lifetime rather than embodied energies because potential lifetime energy reductions through good design are significant. Most OECD countries have set up energy efficiency standards for new dwellings and service sector buildings: this includes all European countries, Australia, Canada, the USA, Japan, Korea and New Zealand. Some non-OECD countries outside Europe have also established mandatory or voluntary standards for service buildings and Singapore and the Philippines were among the first.

To date building codes have not encouraged the use of more energy efficient materials, in spite of the huge impact of materials not only on embodied energies but lifetime energies as well.

Research and Development Funding Priorities

The early North American and to some extent European approach was to “prime the pump” and research global warming. The early Australian approach to sustainability was much cruder and involved the outright purchase of abatement with little research. To date materials science, which the paper demonstrates as fundamental has however received little funding globally.

As of early 2004 European priorities were genomics and biotechnology for health, information society technologies, nanotechnologies, intelligent materials and new production processes, aeronautics and space, food safety and health risks, sustainable development and global change, citizens and governance in the European knowledge-based society. In the USA Federal funding priorities include nanotechnology, defense, and aeronautics.

Geological sequestration has also been a priority in many countries as it is associated with the petroleum industry and doubts have been raised as to the transparency of funding[xli]

To date Australian research priorities have not included materials science however the Australian research funding priorities for 2004 – 2005 may well lead the way globally as included under the heading “Frontier Technologies for Building and Transforming Australia” are advanced materials. “Advanced materials for applications in construction, communications, transport, agriculture and medicine (examples include ceramics, organics, biomaterials, smart material and fabrics, composites, polymers and light metals).[xlii]” The Killer Application – TecEco Cements on page 22 are material composites that include wastes and sequester CO_2.

Recycling

Recycling involves a series of activities by which wastes are collected, sorted, processed and converted into raw materials and used in the production of new products.

Recycling is carried out by individuals, volunteers, businesses and governments. For high value waste recycling is profitable and undertaken by business, usually by buying back wastes, but not so as the value declines. Governments generally have recognized the importance of recycling but have gone about the introduction of recycling through councils and local authorities in completely the wrong way. As the hazards of discarded wastes do not correlate with their value, many wastes are recycled by the authority of legislation or power of producer organisations.

Instead of being forced upon us using good taxpayer dollars for “feel good” reasons, much more effort should have been put into the development of technologies to make the process economic. With market forces driving recycling much more would occur much more efficiently.

The problem is to make the process of recycling less “feel good” and more economic so it is driven by market forces.

Accounting for Externalities - the True Cost of the Techno-process

“…the exponential growth curve of cost associated with negative impacts or "externalities" such as climate change, salinity, acid sulphate soils, river system degradation, or general pollution, has up until now, been a legacy for future generations to deal with. For decades the cash price of goods and services has been artificially deflated, with much of the real cost being outsourced on to the environment.

The costs, however, that are backing up on us - bush fires, dust storms, floods, soil erosion, salinity, changes in disease patterns, hurricanes and cyclones - can often be attributed, at least in part, to climate change. An integral part of the dilemma we have is the denial that anything truly threatening is happening”[xliii].

Accounting systems that recognise the value of natural capital[xliv] are required so that the true costs of sub techno-processes that extract and waste are born by those who gain the benefit of doing so.

Extended producer responsibility (EPR)

EPR incorporates negative externalities from product use and end-of-life in product prices Producers are made responsible for environmental effects over the entire product life cycle so that the cost of compliance cannot be shifted to a third party and must therefore be incorporated into product prices.

Examples of EPR regulations include emissions and fuel economy standards (use stage) and product take back requirements (end of life) such as deposit legislation, and mandatory returns policies which tend to force design with disassembly in mind.

Producers are made responsible for collecting and recycling end-of-life products. Waste-management costs are shifted to those most capable of reducing disposal costs by changing designs for recyclability, longevity, reduced toxicity, and limited volume of waste generated. Disposal costs are reflected in product prices so consumers can make more informed decisions.
The above solutions all involve a cost. What if benefits could be incorporated?

What Governments Should be Doing and Why

Much as been written about the role of governments and the need to bring about common good.

1. The first requirement is that the people in power realise their urgent responsibility to promote sustainability

The democratic system has a fatal flaw in that the outlook of politicians and therefore governments is usually not much beyond the next election. As a consequence policy is generally extremely short sighted and too directly connected to the needs of the here and now rather than mindful of the future.

Change is occurring, sustainability issues are becoming recognised as important but all too slowly.

2. The second requirement is that governments all over the world co-operate to bring about sustainability

Problems on a global scale are not just the concern of one or two countries but all people on the planet. World federalists believe we need a system of democratic global governance on top of (not instead of) national governments. Such a system would provide enforceable legal mechanisms for resolving conflicts and safeguarding the environment. Perhaps they have a point.

In spite of the two UN ‘Habitat’ conferences on urban prospects,[xlv] and their huge impact, cities have not been given serious attention in the mainstream sustainability debate until very recently. For example the World Conservation Strategy of 1980, which first used the term “sustainable development,” paid little attention to accelerating urbanization. The Brundtland report[xlvi] did discuss the issue, but the main emphasis was on the “urban crisis in developing countries.”

The role of the built environment, particularly in rich cities has been neglected; however this is difficult to reconcile with physical reality.

"The world population reached 6 billion in 1999…..At the current rate the world will have 7 billion people soon after the year 2010. The overwhelming share of world population growth is taking place in developing countries (…95.2% in 1990-2000; 97.6% in 2000-10; and 98.4% in 2010-20). The population of developing countries has more than doubled in 35 years, growing from 1.89 billion in 1955 to 4.13 billion in 1990.

Significant proportions of population increases in the developing countries have been and will be absorbed by urban areas (…71.8% in 1990-2000; 83.4% in 2000-10; and 93.4 in 2010-20). Urban settlements in the developing countries are, at present, growing five times as fast as those in the developed countries. Cities in the developing countries are already faced by enormous backlogs in shelter, infrastructure and services and confronted with increasingly overcrowded transportation systems, insufficient water supply, deteriorating sanitation and environmental pollution.[xlvii]"

Since the wealthiest 25 percent of the human population consume 80 percent of the world's economic output[xlviii], approximately 64 % of the world's economic production/consumption and pollution is associated with cities in *rich* countries. Only 12 percent is tied to cities in the developing world[xlix]. In short, "half the people and three-quarters of the world's environmental problems reside in cities, and rich cities, mainly in the developed North, impose by far the greater load on the ecosphere and global commons[l]".

It is time for governments to take an active role, to recognize their responsibility to seek sustainability as a cornerstone to all government expenditure and policy and facilitate economic systems that encourage sustainability such as carbon trading and EPR. The problem is to achieve "common good" without a disproportionate impact on taxation.

Making Reducing, Re-using and Recycling Work in the Long Term without Subsidies or Taxes

Even though governments through policy can introduce change it is important that technologies that seek sustainability are also fundamentally economic otherwise they are inefficient and not viable in the long run.

Economic viability attracts investment, and insufficient investment is finding its way into sustainability. Natural capital is undervalued.

Consider the techno-function:

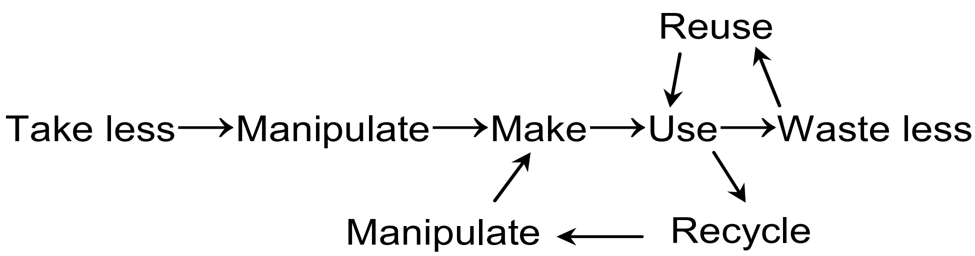
Take⟶Manipulate⟶Make⟶Use⟶Waste

The function has an input and output rate and volume dimension. If the impacts of the techno-function on the geosphere-biosphere are to be reduced then the rate and volume of flows through the function need to be reduced and they are therefore of vital interest.

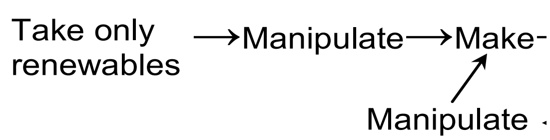
A large proportion of what passes through the techno-process that is not renewable or easily reassimilated ends up as the materials with which we build our techno-sphere. The rate and volume of these flows can be reduced by:

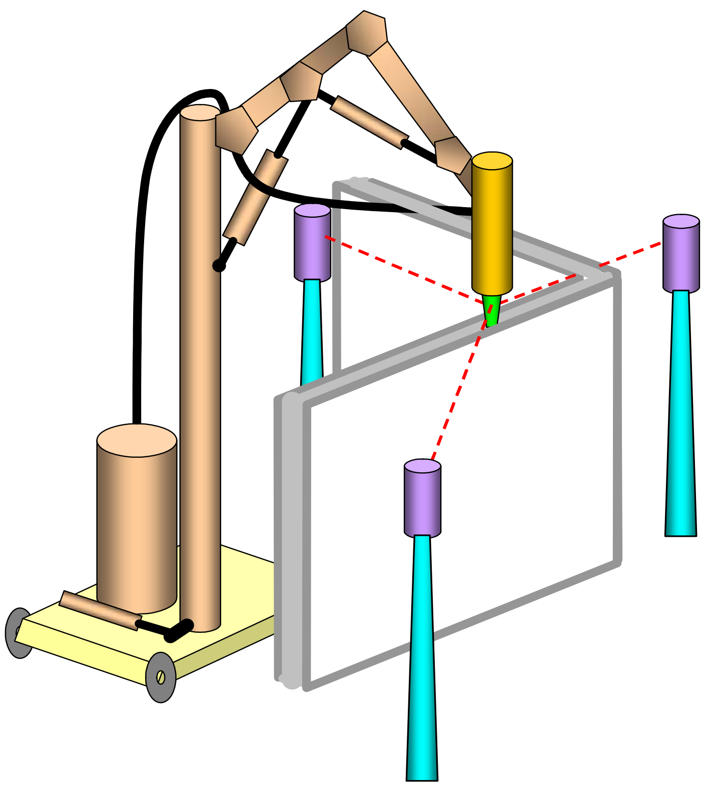
- Reducing the input to produce the same output
- Recycling so that fewer resources are required to be extracted.

By reducing, re-using and recycling the function becomes:



And more desirably:





Reducing the “Take” & “Waste”

The biggest factor in increasing economic growth and raising living standards over time has been the economy’s ability to produce more out of less, i.e. to become more productive.

Productivity is good economics and driven by positive market forces. Productive companies reduce inputs for the same output quality, volume and cost. An increase in productivity would put less demand on natural resources which is something we all would agree is desirable.

Arguably on a personal values scale in the future productivity will become the domain of robots and the challenge will be what we do rather than how efficiently we do it. This is especially true of knowledge workers who in western countries comprise probably three quarters of the work force[li].

Figure 7 - Robot Construction in the Future

For robotics to be used in construction it will be necessary to squeeze self hardening materials out of a nozzle so they just sit without deformation until they gain full strength.

Various materials from structural containing fibres for reinforcement to void filling and insulating will be required and like a colour inkjet printer will be selected as specified by the design.

Accuracy will be far greater than currently possible, wonderful architectural shapes as yet unthought of will be used and fibres will provide reinforcing. Walls will most likely have a low strength foamed insulating cementitious material between the faces making services easy to add at a later time. Conduits could also be provided by design.

The use of robots in construction will reduce the waste of new construction materials immensely. Just like an inkjet printer only uses the right amount of ink, only the exact amount of material will be used. The introduction of robots to construction will also mean more wastes can be utilised for building materials. More self hardening materials will be required, not less and mineral binders like TecEco's new cements have the obvious advantage of being able to utilise a large quantity of wastes (See The Killer Application – TecEco Cements on page 22).

There is no doubt that on a global scale, reducing the rate and volume of inputs required to satisfy the needs of the techno-sphere and output of waste materials that no longer satisfy needs will reduce our detrimental linkages on the environment. The use of Robots is but one practical idea as to how this could be done.

Re-using and Recycling

Before re-using and recycling can become economic the main economic hurdles to overcome are the laws of supply and demand and economies of scale. To do this we need to change the technical paradigm.

Henry Ford leveraged his success selling cars to devise more efficient methods of production. As a consequence he was able to sell his cars more cheaply, increasing sales, providing more money for innovation, which reduced costs even further and so on. Ford was able to sell more at lower prices and yet make more money by achieving economies of scale. The laws of economics rely on positive feedback loops. Industrial economies of scale tend to increase value linearly, while the laws of supply and demand would dictate that exponentially more is sold or used the lower the price for the same quality.

It can however take years before these laws kick in.

For example during the first 10 years, Microsoft's profits were negligible. They started to rise in 1985 and then exploded. The experience of Federal Express was similar. The same applies to fax machines and the internet which similarly festered for some time before becoming ubiquitous.

The question is whether the world can wait for an explosion in the recycling business to take place. There is a desperate need to achieve sustainability quickly. What factor or factors are missing? What will make it happen as a matter of profitable economics rather than policy?

The trouble is that right now it just costs too much to reuse and recycle for these processes to be driven by economics alone. As a consequence government intervention in the form of regulation (Germany, some other countries and some states in some countries e.g. South Australia in Australia to some extent) and subsidies (most of the rest of the developed world) are required for what is no doubt a desirable social outcome.

How can re-using and recycling move beyond the desirable subsidized by tax dollars to the preferred pushed and dragged by sound economics?

Currently it is more expensive to reuse and recycle than to use newly extracted resources. There would be a rapid turnaround in the sustainability industry if this hurdle could be overcome so that it was cheaper to reuse or recycle.

There are two main costs involved in re-using and recycling. The costs of sorting waste streams and then transporting sorted recyclable materials back to a location in which they can be reused.

The second law of thermodynamics (the law of entropy) was formulated in the middle of the last century by Clausius and Thomson. Like most natural processes, waste streams tend to follow this law in that wastes at the point of elimination from the techno-process tend to be all mixed up. Disorder is prevalent for two main reasons; things are made with mixed materials and the waste collection process tends to mix them up even more.

The current technical paradigm for the techno-process generally requires separate inputs. Costs are incurred and waste generated in separating what is required from the balance of material as nature itself rarely concentrates. As mentioned earlier, one study found that around 93 percent of materials used in production do not end up in saleable products but in waste[Error! Bookmark not defined.].

Re-using and recycling is even more uneconomic because the cost of un-mixing even more complex waste streams is prohibitive. After recycling is completed there is a cost of returning the materials back to manufacturers who can use them. Simultaneously dealing with the disassembly/sorting constraints, cost, material problems and transport issues during recycling are critical challenges.

I once had the pleasure of a long discussion with Edward de Bono, the inventor of the words “lateral thinking” about a new technology I have invented that you will hear about later in this paper. He said that what was needed for market success was a “killer” application, an application that just could not help but succeed.

To get over the laws of increasing returns and economies of scale and to make the sorting of wastes economic so that wastes become low cost inputs for the techno-process new paradigms are required. The way forward involves at least:

- A new killer technology in the form of a method for sorting wastes
- A killer application for unsorted wastes

The "Killer" Technology - Silicon Identification of Materials

The means to very efficiently sort wastes may just lie in the silicon chip. The cost and size of intelligent silicon with embedded thought are both falling exponentially. Silicon chips already have a diverse range of uses For example they are being used in paint by car manufacturers for identification purposes and one was recently put in the ear of my dog for the same reason. Silicon chips will one day be as plentiful as what they could be embedded in. They will tell us the cost at the check-out, the manufacturer, warranty details who the owner is and what waste stream a robot should put them into when eventually wasted.

Remember the impact bar-coding had in supermarkets? Silicon embedded in products will do the same thing for the cost of sorting waste streams. Robots will efficiently and productively be able to distinguish different types of plastic, glass, metals ceramics and so on.

The only economic hurdle that would remain would be the efficient transportation back to manufacturing points of these waste streams. This could be overcome with a ubiquitous killer application.

We are progressing towards a silcon intelligence defined flow of materials from producer to consumer. Wal-Mart, one of the biggest US retailers has initiated the introduction of smart tagging of all goods that it will sell in the store. So too have the US defense department for all provisions. Everything will have a tag that indicates what order it was on, delivery details, price, disposal etc. The US packaging giant, Smurfit-Stone want to eliminate the smart label and implant chips directly into packaging. TecEco want to go a stage further and implant intelligent silicon that will do everything everybody wants it to do, directly into the materials out of which things are made.

The Killer Application – TecEco Cements

What if wastes could be utilized depending on their class of properties rather than specific properties? What if an application could be found that could utilize vast volumes of materials that offered useful broadly defined properties such as light weight, tensile strength, insulating capacity, strength or thermal capacity? After all, the best thing to do with wastes is to use them if at all possible.

There are many wastes that are just too costly to further sort into very specific wastes streams such as many plastics. There are also waste streams such as mine tailings, furnace sands, quarry dusts and the like for which no particular use could otherwise be found.

Glasses tend to share in common a lot of properties as do plastics, wood, ceramics and so on. Glasses are brittle, tough and abrasion resistant. Plastics are generally light, insulating and have tensile strength. What if it did not matter if they were mixed up together?

The solution is to use these materials in composites for their properties rather than for their composition. The problem then becomes one of finding a potentially cheap, un-reactive but strong binder with the right rheology for use by for example robots of the future Reducing the "Take" & "Waste" on page 19. Eliminate plastics, epoxies and other inorganic binders that are just too expensive and the choice for durability and cost is a mineral binder. Ordinary Portland cement concretes are a good start; over two tonnes are produced per person on the planet per annum. Unfortunately they are too reactive to use with a wide range of fillers. The breakthrough has been the development of a wide range of blended calcium-magnesium binders with a low long term pH and that are internally much drier.

Sustainability by regulation subsidy or taxes is not itself economically sustainable. The new TecEco binder technologies are a breakthrough in that they change the technology paradigm. "...it is technology that defines what is a resource as well as what our effective supply of that resource is.[liii]" Wastes can be used and in large quantities, there is wealth in waste and significant overall improvements in sustainability are achievable with economic benefits.

A major advantage of the TecEco technology over all other sequestration and abatement proposals it that the technology itself is viable even without a value being placed on abatement and sequestration. Another advantage of the magnesian tec, eco and enviro-cement technologies is that they define improvements in the material properties of concrete.

The TecEco technology is but one very important example of where materials can make a big difference to sustainability by providing composites that utilise wastes. There are other ways improvements in materials will make a big difference.

Materials – The Key to Sustainability

Materials are the lasting substances that flow through the techno-process. They are the link between the biosphere-geosphere and techno-sphere. The use of more sustainable materials is fundamental to our survival on the planet. The choice of materials that we use to construct our techno-sphere ultimately controls emissions, lifetime and embodied energies, maintenance of utility, recyclability and the properties of wastes returned to the biosphere -geosphere.

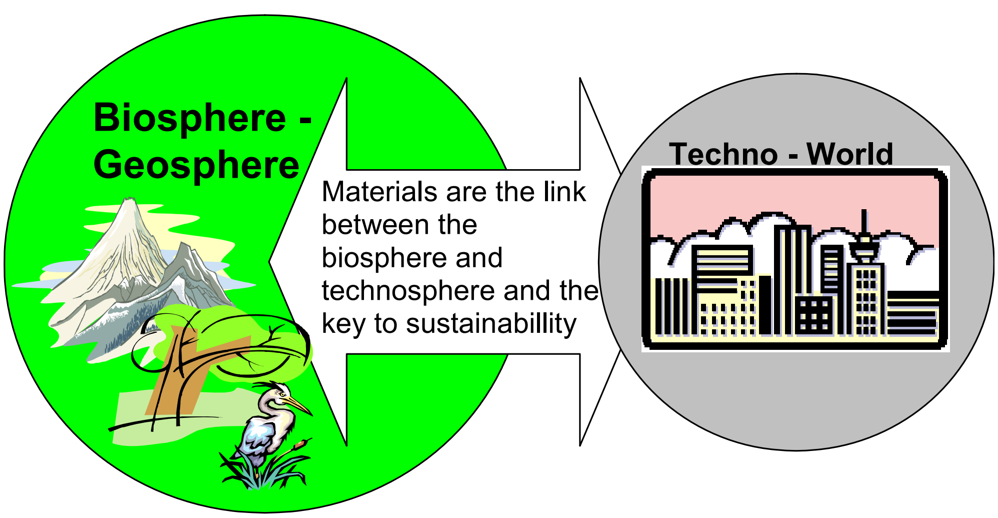


Figure 8 - Materials - The Link between the Biosphere - geosphere and Techno-sphere

Fundamental changes are necessary to achieve real sustainability and if these are to occur without economic disruption, as the materials we use control the sustainability of the systems we proliferate, the materials paradigm we live in will also have to change.

- Materials science will become of great importance as the race to develop materials for the future gets underway

- The properties of many materials are too focussed. It should be possible in the future to develop new materials with more than one property currently considered as conflicting.

- For example materials that are good insulators do not generally have a high heat capacity. Combining insulating and heat capacity has huge potential for reducing the lifetime energies of buildings. Another example is that materials that are light in weight are not generally strong.

- The embodied energy of most materials is too high. In the future it may be possible to develop ways of making existing materials or new materials with the same functionality and properties but with lower embodied energies.

  The new TecEco kiln for example combines grinding which is only 1-2% efficient with heating to reduce overall energy inputs by some 30%

- Materials will be required that are either biodegradable or easily recycled within the techno-sphere techno – process are required.

  An example of a biodegradable replacement for a non biodegradable product includes rice paper takeaway eating containers and utensils instead of plastic. An example of easily recycled materials would be printer cartridges which are economic to return for refilling or polling booths in Australia which are all returned for recycling as paper under the watchful eye of the electorate commission.

- Materials that remain useful for longer are required.

  Things were once and still are to some extent built to break down after the period of their warranty. Henry Ford started this by reducing the quality of the items that lasted the longest in his cars. There is a way forward however. Imagine if functionality and service were purchased instead of energy and things. An example given in the book "natural Capitalism" was that instead of buying electricity one would purchase heating and lighting[liii]. I recently had the pleasure of entertaining in Tasmania the representative of a Brazilian company, Magnesita S.A. He told me that his company no longer just sold refractory bricks. They were paid on the basis of downtime experienced by their steel producing clients. With better quality bricks and less downtime they were paid more.

The Importance of Sustainable Materials for the Built Environment

Urbanization has serious negative implications for global sustainability yet the impact and the associated opportunities for improvement have been given little emphasis.

Given the enormous materials flows involved, the obvious place to improve sustainability is the built environment. The materials used determine net emissions, the impact of extraction, how they can be reused and the effects on earth systems of wastage.

To reduce the impact of the techno - function that describes the flow of these materials from take to waste it is fundamental that we think about the materials we use to construct our built environment and the molecules they are made of.

With the right materials technology, because of its sheer size the built environment could reduce the take from the geosphere-biosphere and utilise many different wastes including carbon dioxide.

Materials used to construct the built environment should, as well as the required properties have low embodied energies, low lifetime energies, and low greenhouse gas emissions when considered on a whole of life cycle basis. They should also be preferably made from renewable resources and either easily recycled or reassimilated by the geosphere-biosphere

The Lesson for Governments

As Paul Zane Pilzer says "Technology is the major determinant of wealth as it determines the nature and supply of physical resources[lii]." Why is it then that so little government research funding is to change the technical paradigm for reducing, re-using and recycling materials? Materials are after all a major part of the flow of resources in the techno function and fundamental for sustainability. Instead of for example like the Australian Greenhouse Gas Abatement program which had little for science and financially supported projects with significant abatement including converting from coal to natural gas, governments need to focus on fundamental research that change the technology factor. As Pilzer's first law or alchemy states "By enabling us to make productive use of particular raw materials, technology determines what constitutes a physical resource[liii]." Pilzer goes on further to explain that definitional technologies are those that enable us to make use of particular resources. Wastes are potentially a huge resource. Improvements in recovery and utilisation technologies will one day make them of significant value.

Fortunately some governments such as the EU are starting to research how we could live more sustainably on the planet. As of today however I am not aware of any country or group of countries that prioritise the development research into materials as a way of reducing the take and waste in the techno - function, maximising utility and making re-use and recycling more profitable.

Concrete - The Material for the Future

As previously discussed under the heading The Built Environment - A Focus for Sustainability Efforts on page 14, concrete is the single biggest material flow on the planet by a big margin. There is tremendous scope to add strength and improve sustainability and other properties of concrete as a material through the addition of other substances including wastes, many of which would add tensile strength, insulating capacity or reduce weight. New composites made in this way will be the high performance materials of the future.

Materials such as the new magnesian tec, eco and enviro-cements will have a role in the development of these new materials as they not only absorb carbon dioxide in bricks, blocks, pavers, mortars and porous pavement, but also improve properties and allow the incorporation of a wider range of materials.

Conclusion

The way forward is clear, technology can help us change the techno process so that we take and waste less. By doing so the process becomes more economic and thus self propelled with less government intervention. Finding 3 under the heading Transport and Urban Design of the recent ISOS conference in Australia applies globally. It stated in part. "…The Federal Government should promote Australian building innovations (e.g. eco-cement) that contribute global solutions towards sustainability; provide more sustainable city innovation R&D funds; and re-direct some housing and transport funds towards sustainable cities demonstration projects[liv]."

Technology can make it possible to achieve a far greater measure of sustainability, to economically reduce, re-use and recycle. The potential multipliers from spending on research and development are huge.

With the development of definitional materials technologies as a result of appropriate research and development funding as Amory Lovins of the Rocky Mountain Institute puts it sustainability "*will happen, and happen rapidly – because it's profitable*[lv]*".*

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