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Environmental Economics of Ethanol Production – a brief introduction

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Abstract

This research has been carried out to establish; the importance of valuing externalities in relating decision making to the triple bottom line of ethanol production. By treating organic wastes as a resource and applying a different method of waste management, organic wastes could contribute significantly to global energy needs. The ethanol distillation process has a waste product - stillage; a soup like waste stream that contains substantial organic content. By digesting this material to optimum efficiency there are three resources recovered – biogas (80% methane), biosolids (high in nutrients equivalent to high grade fertiliser) and recyclable water. Current waste treatment in the ethanol production industry focuses on drying the stillage waste and using the resultant material as mulch to be spread over crops; energy intensive, has little benefit and increases the cost of production. Therefore if a waste treatment process could convert the waste into recoverable resources; such as methane; then the subsequent methane utilised back in the distillation / production process as a source of energy, this would essentially reduce the cost of producing ethanol in accordance with the true costs being considered – in other words making sure all externalities are valued.

Unless an economic advantage can be established, the true benefit of valuing this type of waste treatment is redundant. This relates to the current way in which the economy works. Ultimately all decisions of business and industry relate to the bottom line, the profitability of a project, will the project make money. By putting a value on externalities associated with a project or process it can be shown whether a project will be profitable, even when considering the impact on the environment and society, not just the economy. Ultimately, when all externalities can be quantified and valued and shown to be positive - the project is inherently sustainable

Values for the externalities can be derived from various references such as: current market value. Carbon now has a value per tonne of emissions established in several markets around the world – these values can be attributed directly to energy use. The value of water has been established through research and can also be attributed to water use. The total economic value (TEV) of water, can be broken down into three components: the direct use-value (used or potentially useable by humans); the ecological support value (value to the environment), and the option value (value to society from having the resource available at some time in the future to be used). Ecosystem support value is associated with the assumed contributions of the resource cycles in their naturally-occurring states, or in some similar state, to provide flows to the ecosphere of the area – such as carbon, water and nitrogen. To the degree that the water is removed from the area, as with the industrial uses, for instance, this value is lost. Use value is triggered explicitly by the removal of the water from the aquifer, and its delivery to a specified user, or its storage in a location where it is available for use, in some way, by humans.

Therefore, this research aims to show that within ethanol distillation, by utilising waste treatment to recover resources, using those resources directly in the operation / process / production, valuing all externalities associated both foregone and utilised; the cost of production should decrease when scrutinised from an environmental economic perspective.

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1.0 Introduction

There is clear evidence that climate change is beginning to affect weather systems and well-being and predictions are that these changes will only hasten the decline of our natural environment; an environment that is being constantly pressured to supply the natural resources on which human activity depends so much (IPCC, 2007 and Stern, 2006). Evidence suggests that the pattern of increased concentration of carbon dioxide (CO_2) and equivalents in the atmosphere are the major cause of this change in the climate (IPCC, 2007). The difference is human interference present and through recent history as compared to pre-agricultural and industrial development. Human evolution from hunter gatherer to formalised agriculture to the advent of the industrial revolution have contributed to the increased levels of these gases in the atmosphere by increasing which largely follows from the rate at which fossil fuels are burnt.

The best available science clearly indicates that climate change is real, is happening, and is starting to impinge on our world now; that same science is now unequivocal about the fact that we are the cause (IPCC, 2007 and Stern, 2006). Interestingly, however, public opinion still significantly lags behind the science, and some commentators in the public media continue to attempt to discredit the climate change science (Boykoff and BoyKoff, 2004). Notwithstanding this, the degree to which public opinion has shifted in recent times, is striking; a recent worldwide BBC survey found that 79% of respondents recognised climate change was a serious issue, and wanted governments to take action (BBC, 2007). Industry needs to be mindful of this massive shift in global public opinion, as it will drive higher expectations for corporate environmental performance, manifested through the spending patterns of consumers, the regulations imposed by government, the scrutiny of non-governmental and community organisations, and the expectations of shareholders. If the public wants action on climate change, it clearly wants industry and business to do its part.

It would be remiss of the human species to think that climate change will be fixed by natural processes when the damage is not nature-induced; it would seem the rate at which nature must assimilate pollution of this kind just cannot do so at such a rate; CO_2 is sequestered through carbon sinks – trees, yet we cut down vast tracks of forest to make room for crops and development. It would also be remiss of us to expect a single solution or idea will be able to reverse our impacts. Yet by changing our thinking we can be well on the way to alleviating the human impact on nature. That change in thinking is called 'sustainability'. By considering sustainability in the decision-making process across all sectors and then acting on our insights, our impact on the environment and the subsequent damage we have incurred will hopefully reverse.

Sustainability is both an attitude and a way of life, one that acknowledges the interdependence of human wellbeing with the wellbeing of our environment, our economy and our society. There is little doubt that environmental degradation is a major concern that faces us today and in the future. The emerging paradigm from the Brundtland Report 1987 exemplifies that we must take into account not only environmental aspects, but also economic development and social welfare when we consider the whole process of decision making. It should be noted that one does not function without the other (WCED, 1987). All levels of governments, all industry, all business and communities in all countries, must adopt this approach in every aspect of day-to-day life. It is the cornerstone of sustainable development – linking ecology, economics and social factors.

Climate change is only one part of a wider sustainability context that is becoming increasingly relevant for business. That context is underpinned by the fundamentals of a rapidly growing world population, currently at over 6.76 billion rising by 145 people per minute

(Worldometers, 2008**), all** with the legitimate aspirations of people for a life free from poverty and disease. More people, with greater demands, put increasing stress on the natural environment that provides the food, water and raw materials necessary for prosperity is a major driver of environmental damage. Current global environmental health is challenged by massive forest and biodiversity loss, significantly depleted marine resources, growing atmospheric pollution, and declining and polluted water resources (UNEP, 2007).

Sustainable development is a concept that recognises the need to move from the short term to long term economic, social and environmental aspects into management of all our activities (NSESD, 1992). To be put more simply sustainable development is development, which "meets the needs of present generations without compromising the needs of future generations to meet their own needs", on a global scale (WCED, 1987). With this in mind the issue of climate change and the potential harm that would come from inactivity calls for a global action to a global problem.

A major part of this action directly relates to the use of fossil fuels as an energy source. The global economy has become increasingly dependent on this use for fossil fuels - so much so that it is difficult to imagine life without oil or coal. It is inevitable that the costs of oil discovery and extraction will someday exceed the comparable costs of alternative energy sources, but is this a problem? Such a price disparity will drive the switch from oil to viable alternatives. Indeed, if oil prices continue to increase in the near to medium term due to supply disruptions and other economic factors, this alone will be sufficient to fuel investment in an investigation of potential replacements. However, to date, research and promotion of viable alternatives is slow and attracts much criticism as to their effectiveness. Overcoming scarcity and calibrating supply and demand are things markets do well. So why the opposition to alternative fuels from feed stocks, particularly biofuel feed stocks such as ethanol from corn?

Although ethanol is a realistic alternative, the main opposition comes from the idea that across the whole life-cycle from seed, to planting, to harvesting, to distillation the energy use in all inputs far outweighs the energy output of ethanol (Patzek, 2007). The cost of production is argued not to be viable. A second issue in relation to increased ethanol production is that of using feedstock for fuel rather than food and increasing land clearing to make room for the increase in demand for fuel feed stocks rather than food.

However, the production of ethanol has in itself a waste material from the distillation process that is currently not utilised to its full potential – stillage. The stillage is a soup like waste that at present is dried and spread as a mulch type fertiliser on the ethanol feed crops. Could this waste material be treated any differently? Could the waste material be treated in such a way as to recover resources that are still embedded within in the material?

With the above in mind the main rationale of this research is contained in the following questions:

Will the treatment of agro-industrial high strength organic waste to produce recoverable resources, such as methane, high nutrient feed and recyclable water not only reduce the environmental impact of pollution, but also add to the triple bottom line: environment, economic and social aspects of production processes?

This in turn can be divided into the following research questions:

1. *Will the cost of producing ethanol be reduced by using energy derived from its own production wastes as opposed to using energy use sourced from conventional means?*

Current waste treatment in the ethanol production industry focuses on drying the waste and using the resultant material as mulch to be spread over crops (Lang 2008). Therefore if a waste treatment process could convert the waste into recoverable resources; such as methane and subsequently utilised back in the production process as a source of energy, would this essentially reduce the cost of producing ethanol?

The answer to this question will endeavour to show how the use of effective waste treatment in a new process can ultimately benefit the bottom line of the process. If the answer that the triple bottom line is not improved, the question will nevertheless be worth asking. An insight into triple bottom line and environmental economics is provided in Section 7 of this paper.

2. *Can the resource recovery of these wastes reduce land contamination, overland flow of non-point source pollution and other externalities?*

The generation of resources from treatment of organic waste material, such as from ethanol production, are methane, a biosolid that can be used as stockfeed or fertiliser and recyclable water (Evers 2007). The use of methane for energy will be established in question 1; however, the use of the biosolid could be used as a fertiliser. The biosolid is totally organic and does not involve any chemical or as much energy as conventional fertiliser production (Evers 2001). Therefore, if the use of the biosolid were to be used as an organic fertiliser will this in turn have benefits in relation to land contamination, overland flow of non-point source pollution and other externalities?

This question will endeavour to show how the use of effective waste treatment in a process can ultimately decrease, not change or increase, the externalities involved in relation to the raw materials needed to produce ethanol. This relates to methane to produce energy, rather than using fossil fuel derived energy; the reduction of impacts from producing chemical fertilisers or stockfeeds by creating a single cell protein from waste that can be any alternatives.

An insight into externalities and the importance of accounting and valuing them in environmental economic analysis is discussed in Section 3 of this paper. Section 3 of this paper, Potential for Waste, also applies as it shows how embedded energy contained within organic waste have the potential to be recovered.

3. *Will the energy created be enough to be utilised back in the production system, and can this be evaluated in environmentally beneficial terms?*

Again, the answer can be “yes’ or ‘no’, however, this question endeavours to establish whether the resources that are being recovered will be available to utilise back into the system and effectively reduce environmental harm and increase financial benefit (Hardisty and Cassie 2009). The effective application of environmental economics is essential to establish the overall benefit of resource recovery. A cost benefit analysis and valuation of externalities will be undertaken to help establish the overall benefits of resource recovery.

How this relates to this research will be discussed through literature review of applicable case studies of present methods of waste treatment and is briefly discussed in Section 3 of this paper.

4. *Will this in turn reduce greenhouse emissions?*

This question will explore whether or not the implementation of resource recovery treatment processes will reduce the impact of climate change by producing a renewable energy in methane, reducing the cost of ethanol and therefore establishing a viable cost effective alternative to petrol and the associated reduction in resource use established in questions 2 and 3.

The interaction of the Earth, its cycles and how this relates to human influence and dependence is explained in Section 3 of this paper.

5. *Can developing countries adopt these type of processes and systems and be able to produce their own renewable energy, not only electricity but also ethanol from their crops as a bio-fuel?*

This question hopes to establish the applicability and viability of implementing resource recovery treatment processes to agro-industrial wastes in developing countries and how these countries could ultimately become energy independent or not. Will the developing world be able to adopt this type of technology and resource recovery?

2.0 Methodology

In order to address the research question there are five (5) main areas of investigation that will need to be considered.

1. *How the discipline of environmental economics deals with ethanol for fuel?*

   This will endeavour to show when the true cost of a product is considered, a better understanding will be gained as to the interactions of products in the environment. The research will expand upon the brief introduction to environmental economics and economics of corn based ethanol as discussed in Section 6 and 7 of this paper.

2. *A method for evaluating externalities will be established.*

   This relates to the current way in which the economy works. Ultimately all decisions of business and industry relate to the bottom line, the profitability of a project, will the project make money. By putting a value on externalities associated with a project or process it can be shown whether a project will be profitable, even when considering the impact on the environment and society, not just the economy.

   Based on an environmental economic perspective all elements of a process / industry / business' direct and potential future impacts, positive and negative, need to be quantified in monetary terms to be included in a rigorous decision-making cost-benefit assessment process based on a reasonable social discount rate. If this is done adequately, then any scheme which is economic will be sustainable – society will realise more benefit from them than the costs they incur creating those benefits – and society will therefore both adopt those schemes and ideas and will maintain them over time. Conversely, if overall costs exceed benefits then the scheme or idea is inherently uneconomic and unsustainable – society loses more than it gains, and people will be unlikely to want to proceed with the proposition, or put in effort and resources to maintain it over the longer term. This approach takes the analysis of sustainability firmly into the realm of explicit quantification, and helps to eliminate the qualitative judgement inherent in previous sustainability assessment approaches (Hardisty and Cassie, 2009).

   Values for the externalities can be derived from various references such as: current market value – carbon now has a value per tonne of emissions established in several markets around the world – these values can be attributed to energy use; the value of water has been established through research and can also be attributed to water use - the total economic value (TEV) of water, can be broken down into three components: the direct use-value (used or potentially useable by humans); the ecological support value (value to the environment), and the option value (value to society from having the resource available at some time in the future to be used). For this particular analysis, this designation is useful because to a greater or lesser degree, different options being considered result in the realisation or loss of each of these categories.

   Ecosystem support value is associated with the assumed contributions of the groundwater, in its naturally-occurring state, or in some similar state, to provide flows to the ecosphere of the area. To the degree that the water is removed from the area, as with the industrial uses, for instance, this value is lost. Use value is triggered explicitly by the removal of the water from the aquifer, and its delivery to a specified user, or its storage in a location where it is available for use, in some way, by humans. (Sutherland and Walsh, 1985; and Greenley et al, 1982).

This type of application of quantifying externalities will be utilised in this research and establish the importance of this type of analysis. This is further discussed in the environmental economics and economics of corn based ethanol sections of this paper in Section 6 and 7.

3. *The thermodynamic model for energy will need to be related to all resources and all resource cycles;*

This will show how all resources and cycles of Earth tend to follow the principles of the Laws of Thermodynamics – energy (resources) are neither created nor destroyed and energy (resources) flow in one direction and change one form to another, never reversed. It will be an attempt at showing how thermodynamic principles can be adapted to ecosystem services. It will further emphasise how waste material can be utilised as a resource as it still contains embodied energy and other resources that can be recovered.

A brief explanation of the thermodynamic model and how it pertains to the Earth's cycle's id explained in Section 3 of this paper, which explains how important the interactions of resources within the cycles function and forms a very important role within this research.

4. *The total economic value or environmental economics of ethanol for fuel will need to be established;*

This will indicate the current value of ethanol within the present market as a fuel source, the current full life cycle costs of corn based ethanol will be researched; this has been carried out to some extent in two different studies – Patzek, 2006, "Thermodynamics of Corn-based Ethanol Biofuel", University of California, United States; and Rapier, 2008, "The Economics of Corn Ethanol", Cornell University, United States. There are few studies in this area and the two referenced above are the most extensive found to date. The findings in these studies will show the financial cost basis for corn based ethanol and will provide a baseline of costs for the purposes of this research to build upon with the findings of the cost benefit analysis that will be conducted as discussed previously in point 2.

Preliminary research and some of the findings into the economic costs of corn based ethanol is further discussed in Section 7 of this paper.

5. *It is essential to look at the cause and effect of climate change and establish the interconnectedness of all processes of the Earth.*

Climate change cause and effect (Section 3 of this paper) will be discussed if only in a limited way as this is not the focus of this research, yet forms an integral as it establishes the importance of resource cycles, how this relates to climate change, how this has created demand for biofuels and other alternative fuels and sets the background for this research.

3.0 Background Information

The following sections outline some basic research that sets the background to the proposed thesis question. It is an important part of this research as the sections will indicate that a better understanding of the interconnectedness of the Earth's cycles. It will show how energy can be embedded in organic waste material that is currently not realised in terms of potential energy and resource recovery.

Climate Change and Thermodynamics

In this research climate change will be adapted to a thermodynamic approach to not only the transfer of energy, but also to all resources, processes and cycles of Earth. This is done to show how across the myriad of ecosystem services the laws of thermodynamics can be contemplated as the major cycles of Earth all behave in the relatively same way (Jorgensen et al, 2004). Energy flows from one state to another and never reverses, the same can be said for carbon, water and nitrogen; they all flow from one state to another passing through the ecosystem as part of the process. Essentially everything is interconnected.

The following section will establish the basic science behind climate change and how it relates to the laws of thermodynamics.

Climate Change Science: The Basics

The problem of climate change and global warming is one of excess. There are simply too many CO_2 equivalent gases in the atmosphere than the natural processes can cope with. This has resulted in the Earth's cycles being overloaded. To understand this we need to go back a step and consult Einstein's theory of relativity, or better known as $E=mc^2$. This great insight was to realise that matter and energy are really different forms of the same thing. Matter can be turned into energy, and energy into matter.

With this in mind the laws of thermodynamics come into play. These laws are stated as follows:

1. *"The first law of thermodynamics basically states that a thermodynamic system can store or hold energy and that this internal energy is conserved. Heat is a process by which energy is added to a system from a high-temperature source, or lost to a low-temperature sink. In addition, energy may be lost by the system when it does mechanical work on its surroundings, or conversely, it may gain energy as a result of work done on it by its surroundings. The first law states that this energy is conserved: The change in the internal energy is equal to the amount added by heating minus the amount lost by doing work on the environment."*

In other words energy can be changed from one form to another, but it cannot be created or destroyed. The total amount of energy and matter in the universe remains constant, merely changing from one form to another. Ultimately, energy can be converted from one form into another.

2. *"The Second Law of Thermodynamics states that in all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state. This is also commonly referred to as entropy."*

In other words, the flow of energy can never be reversed. For example a spring-driven watch will run until the potential energy in the spring is converted and drives the time piece itself, it will run not again until energy is reapplied to the spring to rewind it. However, the energy spent within the time piece cannot be reversed, yet it changes from one form to another.

The following section outlines diagrammatically some of the cycles of the Earth's natural processes. It is evident from these diagrams that the transfer of all resources within cycles that each resource simply moves from one state to another, very similar to the laws of thermodynamics. The diagrams show that each resource or process, climate, energy, water and carbon among others, will follow the idea that each is never created nor destroyed, but change from one state to another.

The Earth's Cycles

Our source of energy is the Sun. Millions of nuclear reactions create large amounts of energy. A small amount of that energy reaches the Earth's surface where it is taken up in various processes. The Sun provides many different types of energy: visible light, heat, and ultraviolet radiation. The Earth absorbs only a small percent of the total energy hitting the planet. However, it is enough to moderate the process of entropy.

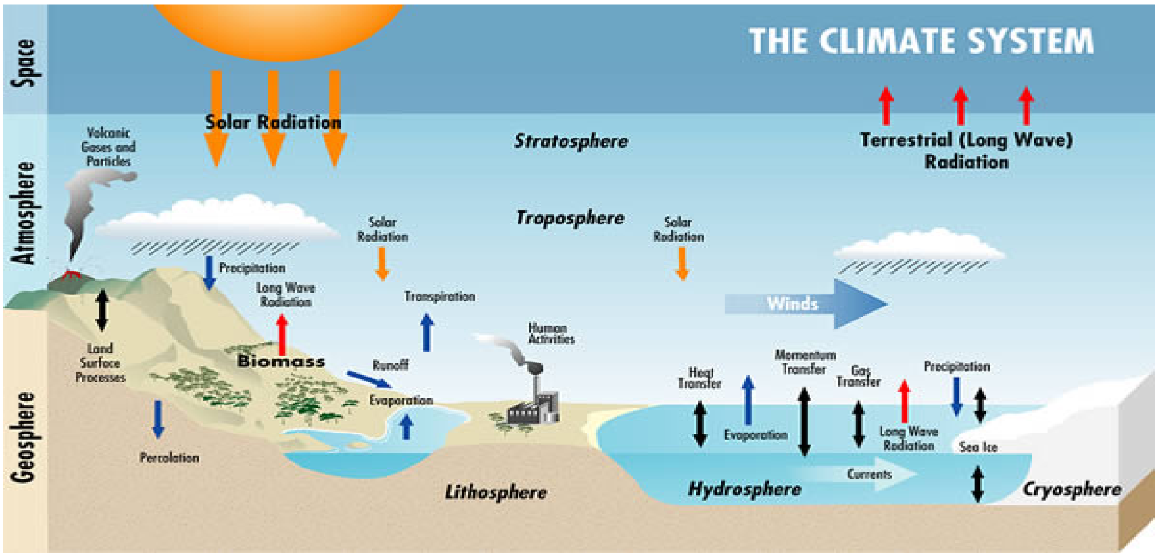

Diagram 1 – The Climate System. (PEW Centre, 2008)

Diagram 1 summarises climate and weather patterns, and how each part is related. Weather patterns such as the Southern Oscillation Index (SOI) and how the effects of El Nino and La Nina impact on the climate of Australia and South America are not shown yet emphasise the natural processes of Earth are by no means local.

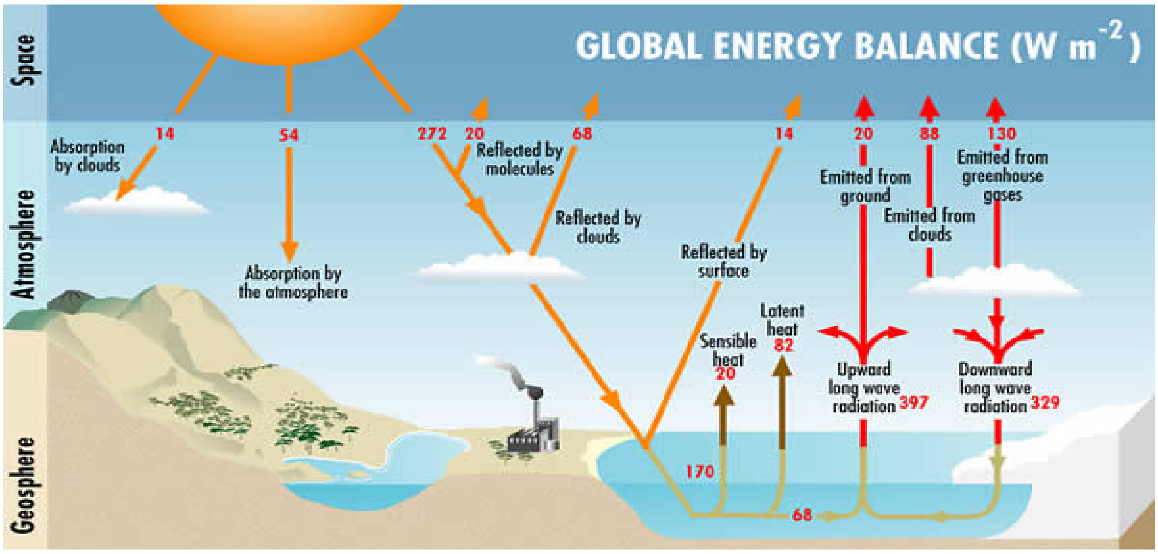

Diagram 2 – The Energy Cycle. (PEW Centre, 2008)

Diagram 2 summarises the Earth's energy balance. It is evident the laws of thermodynamics are in play as the flow of energy is indicated. Diagrams 3 and 4 both follow this analogy with the relation to flow of resources. The basis that all processes on Earth follow the basic rules: matter can never be created or destroyed and that matter is transferred from one state to another.

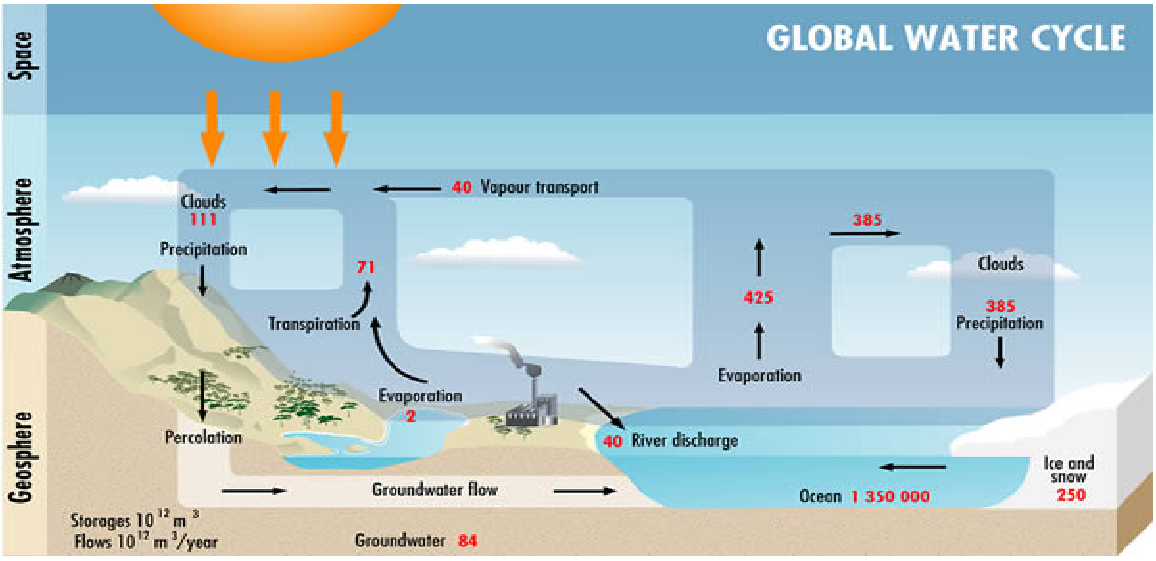

Diagram 3 – The Water Cycle. (PEW Centre, 2008)

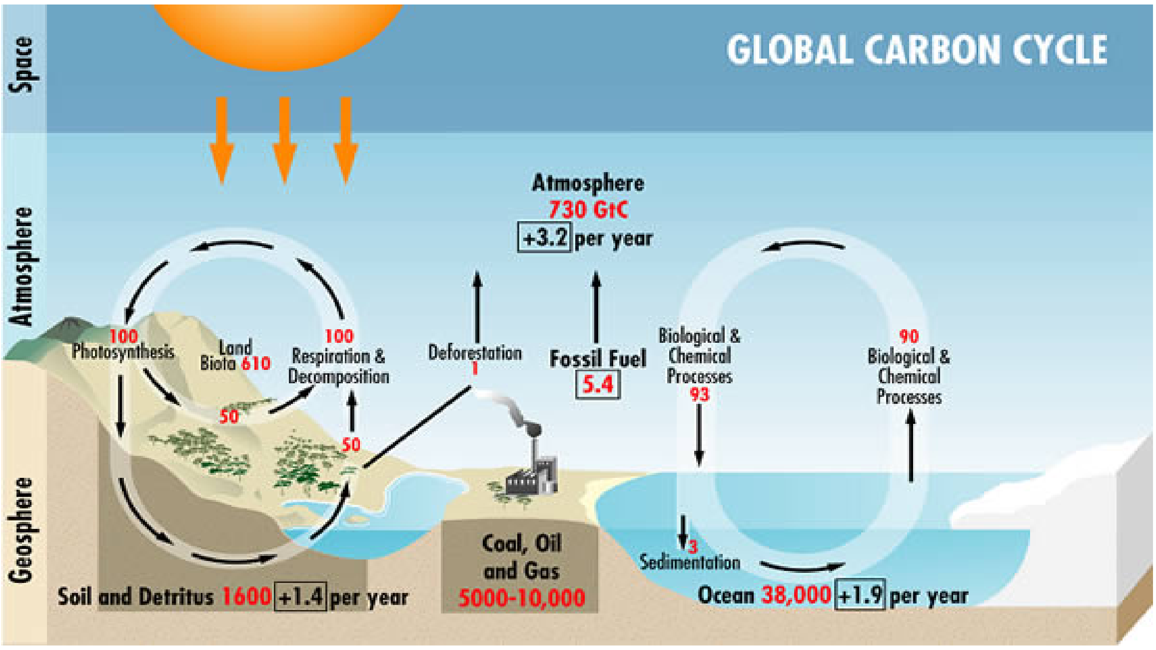

Diagram 4 – The Carbon Cycle. (PEW Centre, 2008)

The problems arise when the flow in one area is increased and the take up or follow-on effects are unable to keep up with that increase. This is the basic issue with climate change and global warming. Human development has simply made too much carbon dioxide for the Earth's natural systems to cope with; the result pollution as global warming. Of course there are more far reaching consequences as a result of this, but what must be emphasised here is that they are purely a consequence of this issue. However, one must ask oneself, are humans influences only to blame?

Human Influence

There are some fundamental disputes about the causes of global climate change; these are between natural causes and the anthropogenic (or human induced) factors. There is evidence to show that natural occurrences such as volcanic eruptions correlate to changes in climatic conditions. The Toba eruption 73,000 years ago is said to have reduced the global temperature to by 3.5 to 5.5 C, almost wiping the entire population of the planet (Miller, 2000).

Over centuries there have been variations in global weather, but these seem to be natural occurrences as far as records can tell (Schneider et al, 2002). However, the earth is not being left to itself to cope as anthropogenic activities have been changing the earth and its climate in significant ways.

Anthropogenic causes are based on human energy use and agricultural practices relating to the production of GHG. With regard to the latter, for example rice cultivated under flood conditions generates methane emissions into the atmosphere as a result of decomposition of organic matter, and deforestation reduces the absorption of CO_2 (DeSombre, 2002). However, the single human activity that is most likely to have had the largest impact on the climate is the burning of fossil fuels such as coal, oil and gas. These fuels contain carbon, burning them releases CO_2 to the atmosphere. Since the industrial revolution of the early 1800s, the burning of large amounts of coal and oil has increased dramatically. This has caused the amount of carbon dioxide in the earth's atmosphere to increase approximately 30%; also average global temperature appears to have risen (Schneider et al, 2002). Figure 1 shows the increase of CO_2 and how it has concentrated in the atmosphere from 1959 to 2007.

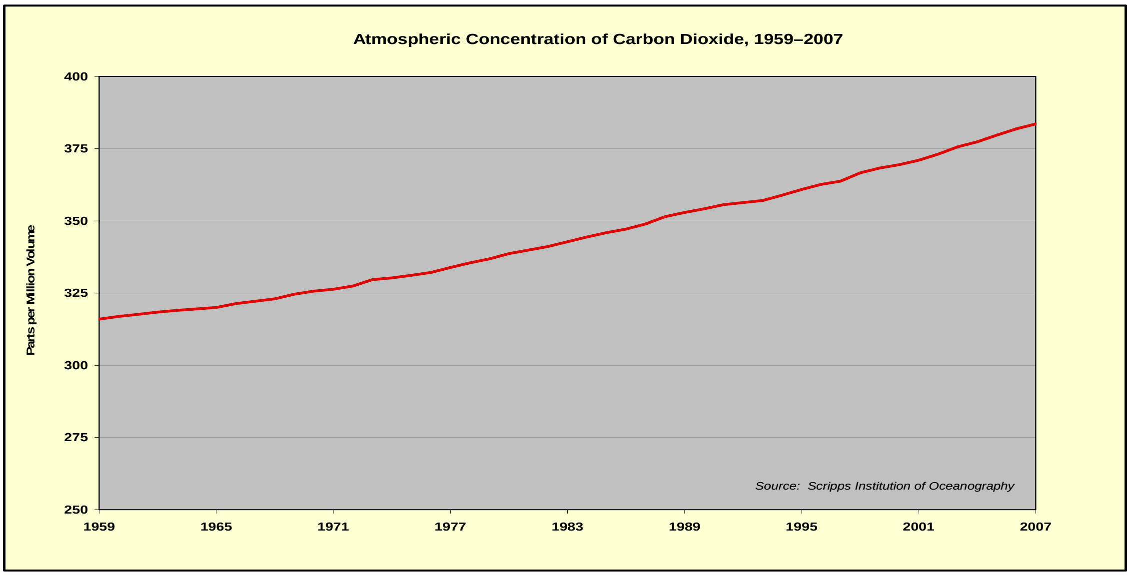

Figure 1 - Atmospheric Concentration of Carbon Dioxide, 1959–2007. (Worldwatch, 2008)

CO_2 traps solar heat in the atmosphere in much the same way as glass traps solar heat in a greenhouse, hence the term "greenhouse gas" (refer to diagram 5). As CO_2 increases in the atmosphere, solar heat has more trouble passing through the atmosphere and the now common phrase “global warming” occurs, potentially causing sea levels to rise due to expanding of the warmer waters, polar ice caps to melt and weather extremes to be more frequent. Media coverage in recent times has alluded the World’s attention to global warming; there is little doubt in the public’s mind that there is an issue.

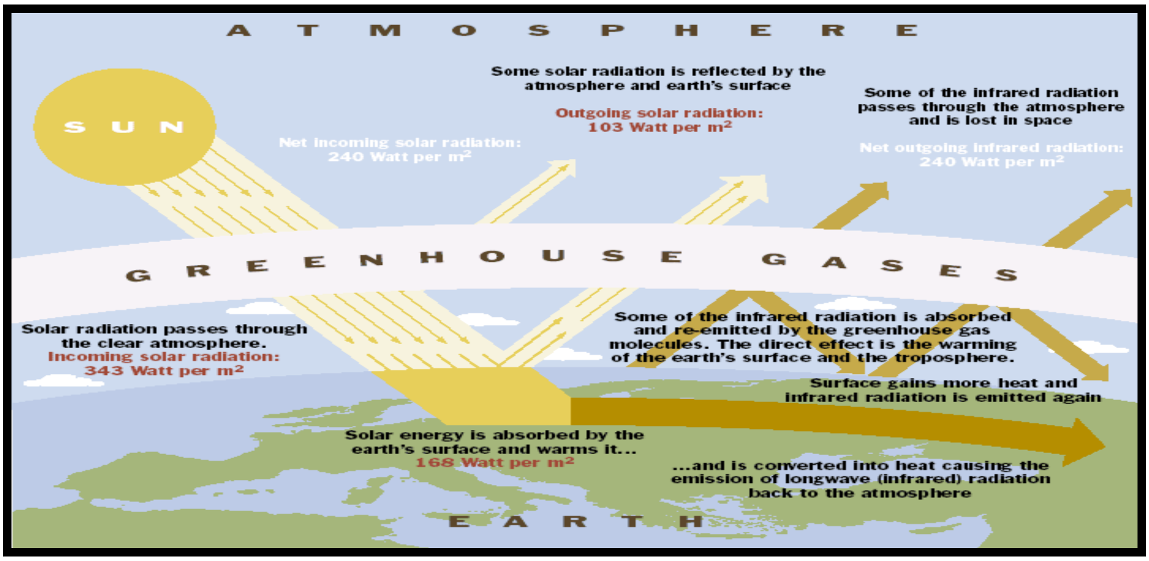

Diagram 5 – The Greenhouse Effect. (PEW Centre, 2008)

While some of the effects of climate change may be positive, such as longer growing seasons in the northern hemisphere which can increase productivity of agriculture and forests, positive impacts are unlikely to be sustained as the globe continues to warm (USEPA, 2002), this is predominantly due to sustained growth. Can agriculture that has been producing a certain amount of crops over centuries at a certain yield keep up with demand as growing seasons increase? Will the land be able to produce high quality crops from the same land, just because the available time to grow them has increased?

Many developing countries are particularly vulnerable to the adverse impacts of climate changes they are less able to adapt given their poor economic situation (that is, lack of technology to combat environmental degradation such as climate change) (UNEP, 2002).

The population of the developing world is rapidly increasing, China and India are showing signs of incredible growth, yet with such an exponential growth of these countries and their economies, there is a corresponding exponential growth of resources. As they grow they are placing tremendous demand on resources to keep up with that growth; Australia's biggest export is coal to China, at present growth rate a coal fired power station is being built each week and China is trying to secure fossil fuels for the future, for example buying out Nigeria's oil reserves (BBC, 2006).

Most projections of future impacts do not address what could happen if warming continues beyond 2100, which is inevitable if steps to reduce emissions are not taken, or if the rate of increase accelerates. The longer warming persists and the greater its magnitude, the greater the risk of climate "surprises" such as abrupt or catastrophic changes in the global climate. It is therefore imperative that global warming is addressed on the global scale with policy implementation that will be adopted, applicable and successful, coupled with technology sharing in new forms of energy production, agricultural practices, pollution control and sequestration.

The increasing need for energy and the depletion of resources is emphasising the need for alternatives measures to be found. The use of waste to create a renewable source of energy has to be a step in the right direction. This will not only alleviate some of the pressure for a reliable source of energy, but can also be adapted the world over (every country has waste issues); it can reduce pollution loads, and even reduce dependency on the energy rich producers of the world.

In all 83% of the world's energy come from non-renewable energy sources (Martinot, 2005). Figure 2 indicates the energy use by sector for both developed and developing countries.

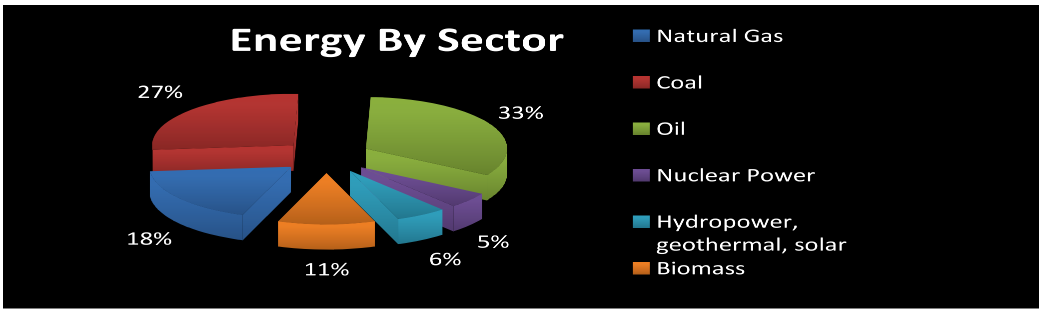

Figure 2 - Energy use by sector for both developed and developing countries.

The question is: are there alternatives that can produce enough energy for the world that are cost-effective and emit far less CO_2 and its equivalents? Are there are alternatives being developed now that could quite easily be adapted to a large scale scenario.

4.0 Potential of Organic Waste for Energy

The following section relates to the application of the precautionary principle, how this will tie into the research topic and demonstrate the potential of utilising resource recovery methods and principles to realise the potential of converting waste organic products to energy and other resources.

It is essential to take the precautionary approach. The precautionary principle in the context of environmental protection is essentially about the management of risk. It is a fundamental component of the concept of environmentally sustainable development (ESD) and has been defined in Principle 15 of the *Rio Declaration (1992).* The precautionary principle states:

"*Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation*."

As noted previously there are still sceptics that believe that climate change is part of the natural process and spending trillions of dollars on something that may or may not exist is simply a waste when there are other issues such as world poverty to address first.

However, as the precautionary principle states, if there is little evidence this does not mean something should not be done to alleviate a potential threat, especially when economic analysis indicates that it makes good business sense to do so. This is the case for climate change. A potentially economic sensible approach is to find viable alternatives to energy from fossil fuels.

As figure 3 indicated there are schemes that currently use wind motion energy, solar power, geothermal and hydropower and the burning of biomass. Unfortunately at present this only equates to 17% of total consumption of energy (Martinot, 2005). Research is showing there is an alternative that could produce large amounts of energy that is currently virtually untapped: organic waste or agri-industrial wastes. There are at present schemes that are able to produce methane (CH_4) through the use of aerobic and anaerobic digestion of these wastes. In fact most sewage treatment plants will produce methane through the normal running of the process (Evers, 2001). The methane created and captured can be burnt for heat energy.

Each and every waste that is created impacts on the environment in some way. Why can we not reduce the impact on our globe and re-use waste, or better still convert the energy potential from these wastes. The untapped potential in our waste products is completely renewable and constant supply. At every step along the human food chain, from farm to table, every operator aims to produce with maximum efficiency one or more marketable food items. Efficiency suffers, however, because each process involved – from production, manufacture, distribution, food preparation – is inherently wasteful, i.e. the food passed on to each succeeding stage contains only some of the biological material received from the preceding one as in diagram 6.

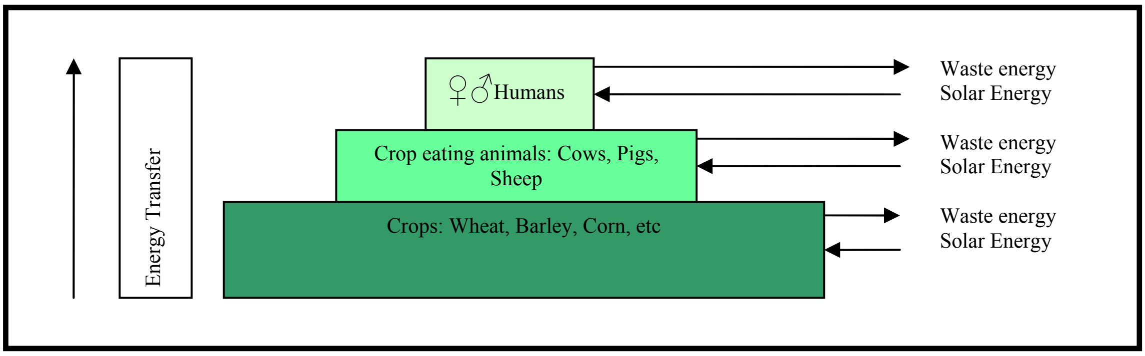

Diagram 6 - Conceptual energy transfer flow of crop to animal to human in the food chain (indicative only, not to scale).

Whenever an economic use can be found for this so called waste, it is generally described as a "by-product". Whenever an economic outlet is currently unavailable, it is a "waste". When one considers the amount of organic wastes that are currently treated to strict standards and simply dumped the energy potential to be recovered is lost. The types of waste that could be targeted for this type of resource recovery are: human waste (sewage), waste from abattoirs, dairies and food processors, wastes from farms, feedlots and corrals, and the waste involved with large scale ethanol production; the list goes on.

Accumulating experience seems to be indicating that the successful solution to any individual waste management problem is unlikely to involve just one single process, but rather a combination of processes, and a combination of wastes. It would seem that any organic waste could be treated and recovered in this manner.

Treatment systems have been developed in Europe, based on an innovative concept whereby agricultural wastes from multiple sources are delivered to a central treatment plant (Evers, 2001). The design is based on the principles of resource recovery and total waste management, incorporating: two stage anaerobic digestion; aerobic digestion; solids dewatering; and filtration, leading to energy generation, organic fertiliser production and water recycling (Evers, 2001). The generation of by-products is optimised with complete odour control whilst treating the wastes by the introduction of selected microbial cultures under the principles of bio-augmentation. Diagram 7 is a schematic indicating the full process.

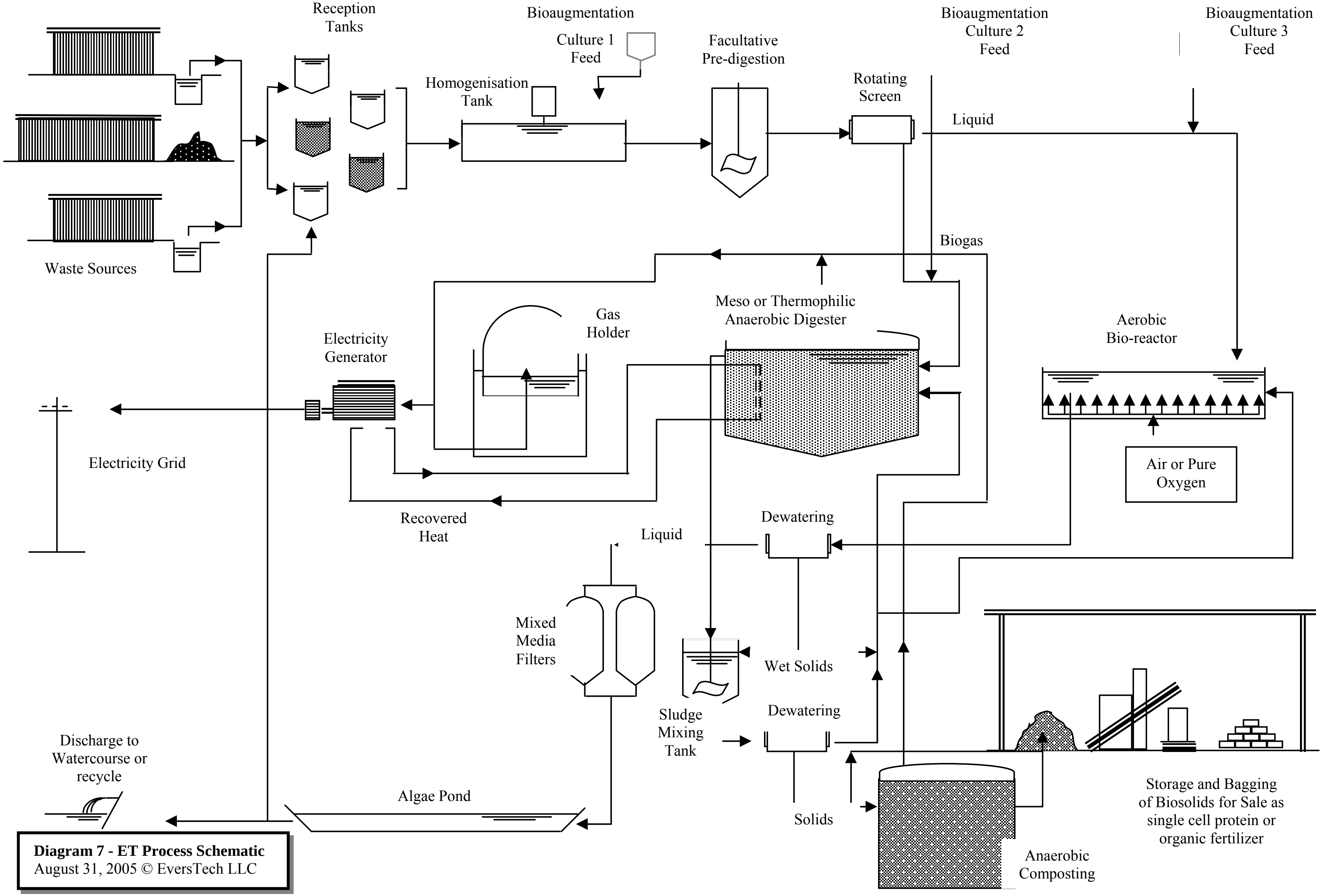

Diagram 7 - ET Process Schematic
August 31, 2005 © EversTech LLC

Animal production farms and other related industrial activities (such as abattoirs, agriculture, breweries, dairy processing, cork processing, dairies, distilleries, ethanol and biofuels production, food preparation and canning, fruit and vegetable processing, meat processing, oil and grease, paper, pulp and cardboard and any other process producing waste with a high organic content) generate wastes in such a quantity and quality that an appropriate management of those residues is difficult without causing pollution to the surrounding environment, and these industries could potentially all use this type of system.

The technology implemented in this promotes maximum resource recovery through the production of biogas and organic fertiliser or single cell protein for animal feed. The biogas is used to produce heat for energy that could be used in the plant and the surplus could be sold to the grid or industrial users nearby. The solid material could be bagged and sold as nutrient rich, organic, slow release fertiliser, or a single cell protein that could replace the requirement for meat meal, which itself has inherent dangers of spreading disease such as Bovine Spongiform Encephalopathy (BSE) (mad cow disease). The treated water could be recycled into the process or for use by others, or used to recharge aquifers or other water storage systems. Diagram 8 indicates the inputs and outputs of the technology.

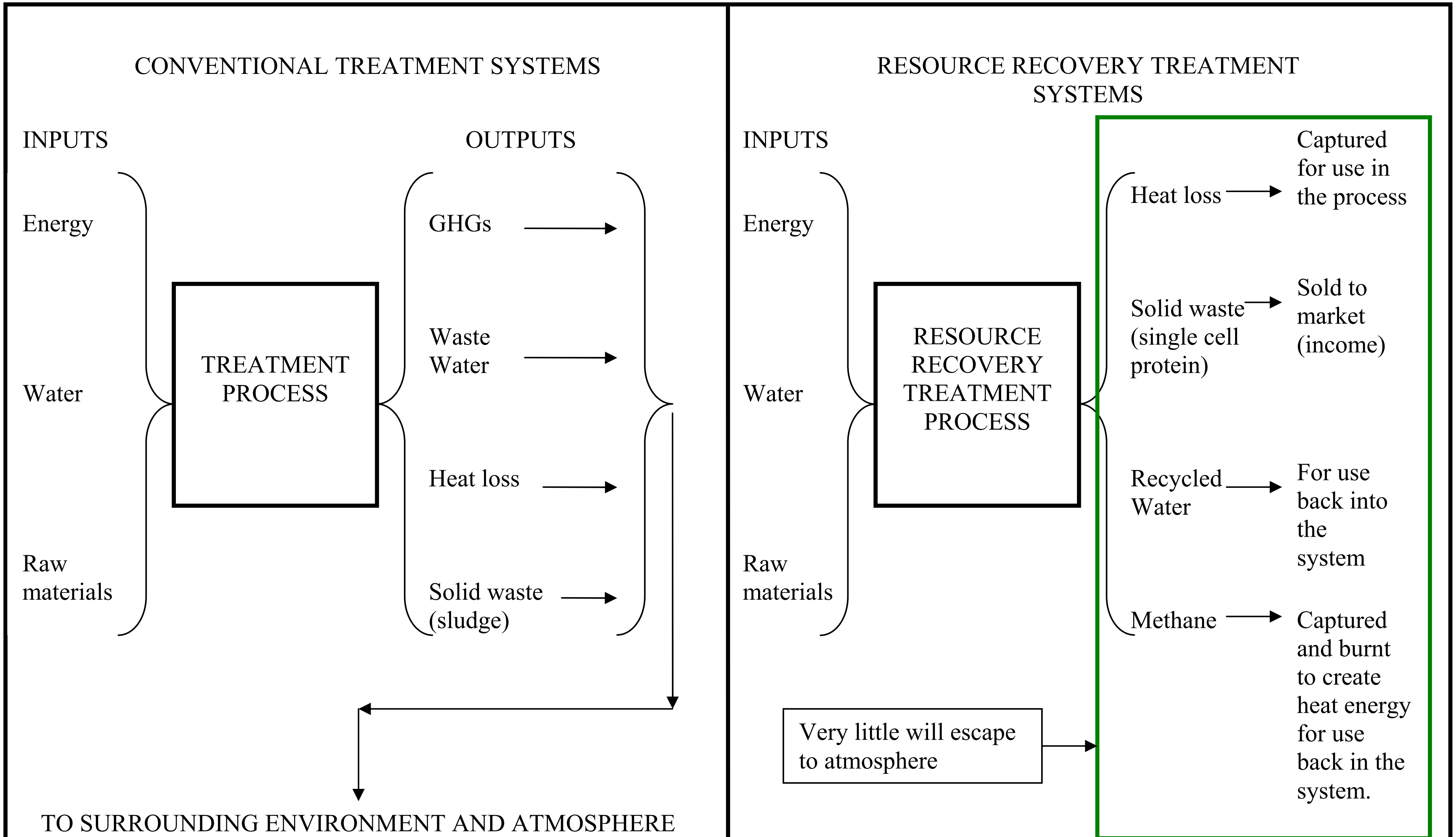

Diagram 8 – Inputs and outputs of resource recovery

Consider this treatment process and adapt it to all organic wastes, the potential for energy production to come from wastes could be considerable. The scenario of a major population/industrial centres being able to produce a major portion their energy needs from the organic wastes generated by their residents, together with contributions from surrounding agricultural, agri-industrial and organic waste producing industries would be a major step in not only alleviating the need for fossil fuel generated energy, but in alleviating the impacts of climate change.

5.0 Background on Ethanol and Production

The following section is a literature review of relevant texts that illustrate how oil reserves are being depleted, the need for alternatives to be found, the need to refine those alternatives to make them more economically viable and how treating the wastes associated with the alternative fuels production process in a different way provides scope to make alternatives more economically viable.

Kenneth Deffeyes (2005) Matthew Simmons (2005) and various others confirm the analyses by M King Hubbert (1953) in relation to the peak of oil production. Peak oil is the point at which the maximum global petroleum production rate is reached, after this point the rate of production enters decline. The idea is that after the point of peak oil the cost (in terms of the amount energy needed for extraction) involved in the production of oil (as in extraction from the ground and refining into petroleum products) will be far more than the return gained. Effectively it will cost more than a litre of oil to extract a litre of oil. A looming problem as the cost of oil increases daily.

Hubbert suggested that if global consumption is not slowed before the peak, the availability of conventional oil will drop and prices will rise, perhaps dramatically. The Peak is still reached but time will allow for a phase-in of alternatives. Hubbert’s model, now called Hubbert’s peak theory, has since been used to predict the peak petroleum production of many countries, and has also proved useful in other limited-resource extraction policies. According to the Hubbert model, the production rate of a limited resource will follow a roughly symmetrical bell-shaped curve based on the limits of exploitability and market pressures.

Deffeyes (2005) and Simmons (2005) both take this analyses further and establish that the peak of oil has been passed and oil production is in slow decline. Assuming they are correct, this puts greater emphasis on finding viable alternatives to oil production and petroleum-based products.

An ever-increasing demand for oil based products such as the current booming Chinese economy and continued unrest in the oil producing countries in the Middle East can and will culminate in sharp increases in the cost per barrel of oil. This in turn is leading to an increase in interest in alternative fuels, in particular bio-diesel and ethanol, as can seen from figure 3 in relation to biodiesel and ethanol production from 1975 – 2007.

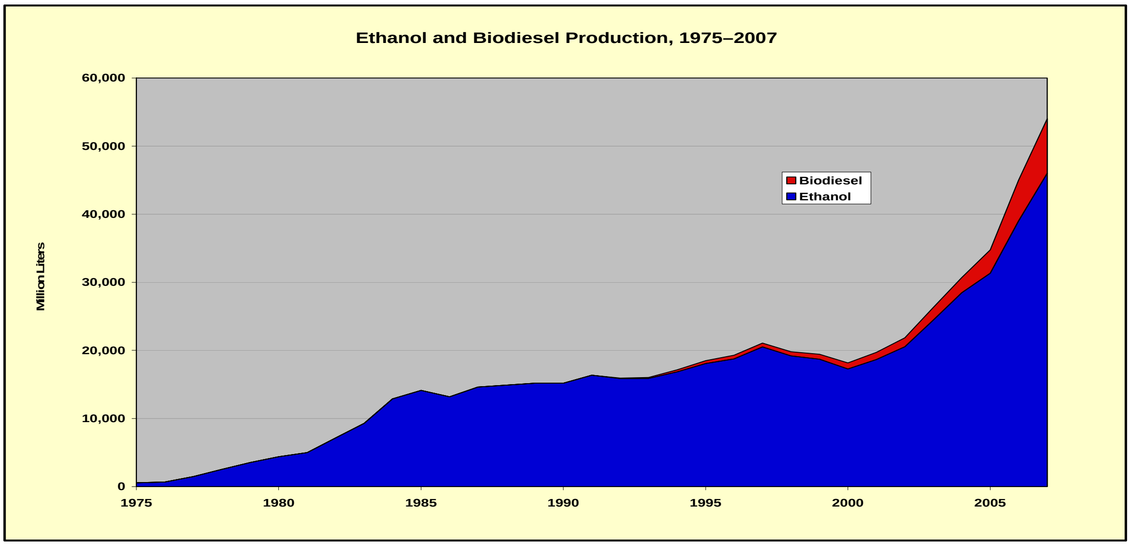

Figure 3 - Global Ethanol and Biodiesel Production, 1975–2007. (Worldwatch, 2008)

There are varying opinions as to the benefits of ethanol as a viable alternative to the production of petrol. Bourne (2007) and West (2006) describe the benefits. They confirm that all things considered equal, ethanol is better for the environment than petrol. Ethanol-fuelled vehicles produce lower carbon monoxide and carbon dioxide emissions, and the same or lower levels of hydrocarbon and oxides of nitrogen emissions. They point out that ethanol production income for farmers who produce the feed stock and create other jobs in the production processes. If ethanol is produced domestically, from domestically grown crops, it reduces dependence on foreign oil, increases the energy independence and has a positive effect on trade. Figure 4 indicates the rate of production of ethanol from the United States, Brazil and the rest of the World from 1975 to 2007.

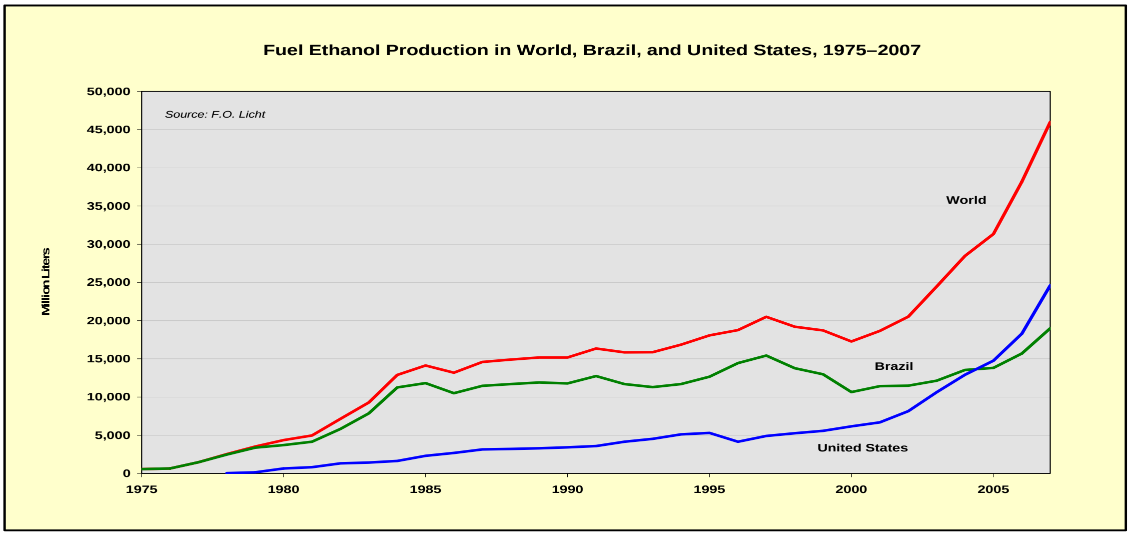

Figure 4 - Fuel Ethanol Production in World, Brazil, and United States, 1975–2007. (Worldwatch, 2008)

However, opposition to ethanol stems from various analyses of the cost of production. The International Monetary Fund (IMF) (2007) is against an increase in ethanol production as a viable alternative to petroleum. The IMF state that the totality of the costs and benefits of ethanol production are not clear, arguing that corn-derived ethanol production depends on subsidies. The IMF concludes that only ethanol from Brazilian sugar is less costly to produce than petrol at the moment, mainly due to different farming practices (Brazil use less machinery in farming by using more labour to harvest the sugar cane, thus reducing the inputs of energy intensive farming into the production of ethanol).

The argument about the worth of ethanol from corn has much to do with different methods of analyses according to David Pimentel of Cornell University (2007) and a very similar study by Patzek of University of California. The studies that Pimentel and Patzek carried out indicates that cost of production of ethanol is more than the cost of production of petrol due to the cots of inputs needed to grow the corn and the machinery needed to harvest the crop. Pimentel argues that it takes 1.7 times more energy to produce a litre of ethanol as compared to a litre of petrol when all inputs are considered. Pimentel also states that corn is not as feasible as other feed stocks such as sugar cane, switch grass and wood chips. These other crops contain a higher yield potential for ethanol, as figure 5 describes yield potential of different crops for biofuel production.

FUEL SOURCES

CROP	USED TO PRODUCE	GREENHOUSE GAS EMISSIONS* Kilograms of carbon dioxide created per mega joule of energy produced	USE OF RESOURCES DURING GROWING, HARVESTING AND REFINING OF FUEL: WATER	FERTILIZER	PESTICIDE	ENERGY	PERCENT OF EXISTING U.S. CROP LAND NEEDED TO PRODUCE ENOUGH FUEL TO MEET HALF OF U.S. DEMAND	PROS AND CONS
Corn	Ethanol	81-85	high	high	high	high	157%-262%	Technology ready and relatively cheap, reduces food supply
Sugar cane	Ethanol	4-12	high	high	med	med	46-57	Technology ready, limited as to where will grow
Switch grass	Ethanol	-24	med-low	low	low	low	60-108	Won't compete with food crops, technology not ready
Wood residue	Ethanol, biodiesel	N/A	med	low	low	low	150-250	Uses timber waste and other debris, technology not fully ready
Soybeans	Biodiesel	49	high	low-med	med	med-low	180-240	Technology ready, reduces food supply
Rapeseed, canola	Biodiesel	37	high	med	med	med-low	30	Technology ready, reduces food supply
Algae	Biodiesel	-183	med	low	low	high	1-2	Potential for huge production levels, technology not ready

* Emissions produced during the growing, harvesting, refining and burning of fuel. Gasoline is 94, diesel is 83.

Source: Martha Groom, University of Washington; Elizabeth Gray, The Nature Conservancy; Patricia Townsend, University of Washington; as published in Conservation Biology SEATTLE P-I

Figure 5: Biofuel crop comparison chart (Seattle P-I, 2008).

Kotbra (2007) indicate that the current use of distillation waste as a dried feed stock is uneconomical. What is called Dried Distillers Grain (DDG) refers to the waste material from the distillation process of ethanol. It is simply the liquid waste known as stillage, de-watered and dried. At present DDG is transported to the corn growers and used for mulch on the crop. Recent research into the use of the DDG treated to produce methane for energy was proven to be inefficient. This was mainly due to the amounts energy needed to de-water and dry the stillage and transport the DDG for treatment. This suggests that an effective waste treatment plant at source might be the solution.

However, the net costs and benefits of this type of treatment need to be quantified in order to ascertained if there is and advantage to this type of treatment. Evers (2005) states that an initial financial assessment into resource recovery and heat energy from the waste stillage, suggests the idea of an effective treatment process for ethanol distillation can potentially reduce the cost of production of corn ethanol. However, this type of assessment does not include the environmental costs and benefits of this type of treatment, an essential task of this research.

Johanssen, McCormick, Neij, and Turkenburg (2006) indicate a major disadvantage in using corn and other crops for ethanol production rather than corn production for food crops is the impact on food prices. Will farmers produce more corn for ethanol to keep up with demand and as a consequence will food shortages occur? Will the increase in demand for ethanol feed stocks increase the need for crop production for fuel, and as a consequence will this lead to an increase in food crop production to cope with the increase in demand? Will the increase in demand as described lead to an increase land clearing to keep up with demand for crop production? Today much of the debate about corn-based ethanol centres on such questions.

This research will establish the costs and benefits of resource recovery in relation to ethanol production from corn feed, and ascertain whether or not there are economies in this approach, and whether this will reduce demand and mitigate the price increases for corn as food.

6.0 Environmental Economics

The general framework that will be adopted as a major part of this research relates to environmental economics. A brief explanation of what environmental economics is, how it relates to this research, and ultimately how it will help address some of the questions identified in the methodology will all be addressed in the following section.

It is now commonly accepted by the scientific community that the predicted effects of climate change, if emissions continue to grow unchecked over the next 30 years, are potentially severe, global in scale and extent. By 2050, even if a post Kyoto approach is needed is implemented by 2010, the average global temperature as expected to rise by 2^0C higher.

To aid in the mitigation of climate change there is a need to apply sustainability principles in varying different ways and in particular link economics to the environment in decision-making at all levels (as the Brundtland Report p187 argued). This can be achieved by adhering to the principles and practices of environmental economics.

Environmental economics is based on the partnership of conventional economics (how people make their living, procure food, provide roofs over their heads and many other necessities that they might require (Hundloe, 2008 and Common, 1995), and ecology (which deals with the habits of living organisms, modes of life and their relationship to their surroundings (Hundloe, 2008 and Common, 1995)). Environmental economics is based on a human perspective and is therefore anthropocentric. The way humans make their living has to be related to the surrounding environment within which they live.

Ultimately environmental economics is a mode of thought and analysis which promotes sustainability; the need to meet the needs of present generations without compromising the needs of future generations (WCED, 1987). This is intergenerational equity criterion. There are limits to the amount of resources which the present population can use before future generations are denied equal per capita amounts.

It would seem that not only are we to integrate ecology and economics, but several other disciplines should not be overlooked, as environmental decisions have to relate to politics and sociology (Soderbaum, 2000). Sustainability applies to all aspects of human endeavour, and the disciplines humans apply to seeking a better world. To understand the importance of environmental economics in modern society, it is necessary to compare it to the old-fashioned environmental management ethic. The previous management system focused on how humans can use the eco-systems to enhance human wealth and welfare (Farber, Bradley, 2000), but tended to downplay nature's limits ("The Limits of Growth" thesis which was developed by Meadows et al 1972 and revisited in 1992 and 2002). A feature of the old paradigm is the optimistic belief that given enough time and technical skill, the decline of natural resources can be reversed (resources replaced) by human technology. This is also known as weak sustainability where nature's capabilities will be substituted by technology, and hence keeping incomes consistent. While we patiently wait for this technology to appear, the rate of non-renewable resource depletion is ever increasing and climate change is threatening.

The old paradigm accepts the concept of discounting the future. By this we mean that an activity that has immediate or short-term benefits, but major environmental implications for future generations, is deemed to carry less and less weight the further into the future we look (Pearce, Turner, 1990). The higher the discount rate the quicker the depletion of those resources occurs. The future generations are downplayed. The ideals of sustainability are dismissed.

Taking up the sustainability challenge modern environmental management puts emphasis on how ecosystems work, how ecosystems are critical for survival, and therefore the careful maintenance of the ecosystems is essential to maintain a healthy economy now and in the future. Strong sustainability dismisses the assumption of substitutability between human-made and the natural. Sustainability and environmental economics are the building blocks of modern environmental management.

If we are to have enough resources now and in the future we must use environmental economics principles, strong sustainability and a zero discount rate. Strong sustainability puts the emphasis squarely on only using resources so that they can be replenished at the same rate as they are being consumed (for every tree that is cut down, one should be planted in its place). In the case of non-renewable resources, such as oil and coal that are replenished only on geological timescales, we must obviously look at alternatives to provide society with the energy that drives modern society – renewable sources. This suggests the Hartwick Rule which means employing the costs from fossil fuel exploration and investing them in replacement (renewable) energy sources.

A major characteristic that is common with all environmental problems is the issue of externalities. This is in relation to the way in which markets operate with respect to the environment. Today the costs involved with making a product are really only reflected as costs of production, they do not take into account the cost to the environment (pollution) and the degradation of eco-systems that produce the raw materials to make the product. The pollution that is created in making the product can have uncosted impacts as it is carried downstream or into the atmosphere or to neighbouring businesses or properties. These costs are not reflected in the price of the end product and ultimately market failure arises (Hodge, 1995). Eventually, everything not accounted for appears in someone's accounts, the non-financial becomes financial. The effect of using petrol as our major transport fuel and the resulting impacts on climate is a classic example of an externality.

Putting a value on externalities can be done. It is about valuing eco-system goods and services. For example, mangroves in the Northern Everglades, Florida have just been valued at US $1.75 Billion for 187,000 hectares in a bold plan by the Florida Governor to buy back crop land to help replumbing of the natural water system to bring back the Everglades (Grunwald, 2008). This puts a price on mangroves and can be applied if the mangroves are destroyed. Carbon dioxide emissions now have a value per tonne due to the emerging carbon trading schemes; at the time of writing carbon was valued from $20 to $50 per tonne depending on which market was considered. Water is increasingly being valued. Ecological value, irrigation value and domestic value can range from $1.50 to $3.50 per kilolitre, depending on where and how the water is used

With relation to the global commons, if something is not owned then it gets exploited. An example of this is our oceans beyond the geographical limits of national exclusive economic zones (320 km). Fisheries are getting fished out, migratory routes of fish are changing and species are becoming extinct (McPhee, 2007). And then there are oil spills and pollution in the global commons. This degradation occurs due to the fact that no one owns the oceans (or atmosphere or space). Climate change falls into this category: exploitation and pollution of a global commons – the atmosphere.

Consideration of environmental, economic and social factors (the triple-bottom line) for the product lifecycle is essential for a sustainable future. Environmental economics makes sure the triple bottom line is being factored into every decision, every process and every product. When the use of petrol is considered one would need to regard the following factors: the environmental cost related to the extraction of the oil, risk of hydrocarbon leaks in accessing the oil, operation of machinery (creating greenhouse gases) while extracting. Then there is the need to refine the oil in order to produce petroleum products, the vast amount of greenhouse gases involved in this process and the energy needed to produce the products; kerosene, diesel and petrol. Ultimately the petrol being burned in the engines of the vehicles that use the oil-based products driving millions of kilometres each year are producing orders of magnitude more greenhouse gases. This is very simplified, yet emphasises the impact petrol and diesel has on the environment. Yet could world economies survive without petrol or a substitute? Most definitely not, dependence is too great.

What alternatives fuels exist? Those which can be phased in as we gradually phase out the fossil fuel economy? Those which – in due course – will replace it completely? Are all alternatives viable? Although biofuels are deemed to be a growing alternative to petroleum products, there is increasing opposition to the use of them, ethanol particularly. This is based on the amounts of energy needed to produce it as compared to the energy output. A genuine concern. What is the point of using an alternative when it puts added stress on not only fossil fuel use to produce, but food also?

7.0 The Economics of Corn-Based Ethanol

The 2005 hurricanes in the Gulf of Mexico demonstrated the effect a natural catastrophe can have on world economies. A litre of petrol increased from $0.90 to $1.40 in Australia alone. The push for alternatives such as ethanol blends increased. Public demand has placed pressure for research into alternatives, and this research is essential. In 2000/01 approximately 18 billion litres of petrol and 12 billion litres of diesel were consumed in Australia (AIP, 2001). Currently blends of 10% Ethanol to 90% petrol is being sold at the bowser.

With this in mind, research into a product that can replace petrol is increasing; a product that can do this and be produced from renewable resources would be doubly beneficial. However, oil has such a strangle hold on world economics, a viable alternative to petrol would seem to be difficult to obtain. Therefore we must compromise and except that oil and petrol are definitely here to stay (until they run out), but viable alternatives that complement their continued use while reducing GHG emissions and strain on non-renewable resources would benefit the Globe and everything on it.

As part of the solution to the recent energy crisis there has been increased awareness and use of ethanol and ethanol blends for vehicle use. 10% blends are common at Australian petrol bowsers, in the US blends of up to 85% ethanol to 15% petrol are ever increasing and in Brazil cars are sold engineered in such a way as to be able to run on blends of 100% petrol to 100% ethanol (Baker and Zahniser, 2006).

As discussed earlier the opposition to ethanol derived from food stocks has been increasing in recent times. Opposition varies from the actual use of food grains to be used to make the ethanol instead of grown for food to the economics of ethanol all together. Some believe that it is actually energy negative when compared to petrol (USDA, 2007 and Patzek, 2006).

7.1 Facts

The US is the single largest corn producer in the world. Large overproduction of subsidised cheap corn forces corn producers and processors to invent new uses for their product. Two corn products – ethanol and high-fructose syrup – stand out (Pollan, 2002; Elliott et al., 2002). About 13% of the US corn production is now diverted to produce ethanol.

A telegraphic description of the US corn farming and processing is as follows (unless otherwise stated figures have been sourced from USDA):

- Corn is the single largest US crop (a record 300 million tonnes of moist corn grain in 2004);
- Corn is harvested from 30 million hectares, roughly the area of Poland or Arizona, and a bit less than 1/4 of all harvested cropland in the US;
- The recent average yield of moist corn grain has been 8,600 kg/ha (and a record 10,100 kg/ha in 2004);
- 42% of world's 708 million tonnes of moist corn grain (CBOT, 2006) in 2004 was produced in US
- All of the US corn fields are fertilised.

Corn requires more fertiliser than any other major crop; 40% of all nitrogen fertiliser goes to corn (Frink et al., 1999).
Corn erodes soil much faster than it can rejuvenate by natural processes.
Corn needs 100 cm water per year, 15% of corn is irrigated.
Between 1995 and 2003, USDA distributed US $37.4 billion, or US $2 – US $7 billion per year, in corn crop subsidies. Recipients of payments made through most cooperatives, and the amounts, have not been made public;
From 1995 to 2003, the top 10 percent of corn subsidy recipients were paid 68 percent of all corn subsidies. The mean payments were US $465,172 each for the top first percent, and US $176,415 each for the top tenth percent of recipients. The bottom 80% of farmers received mean payments of US $4,763 each.
Over 12 billion litres of corn ethanol was produced in the US in 2004.
US goal: Produce 20 billion litres of ethanol from corn annually.
Ethanol producers receive US $3 billion annually from the federal government and state governments, and extract US $2 billion from the environment.

7.2 Energy Inputs of Corn Production and Ethanol Production

Conversion of corn grain into 100% ethanol is a fossil energy-intensive process, which also generates significant gas emissions, as well as liquid and solid waste. Only wet-milling of corn to convert it into glucose will be considered for the purposes of this research. The glucose is subsequently fermented to industrial beer, and distilled to 96% ethanol. The final water removal is achieved in molecular sieves that exclude water, or by distillation with benzene. Fermentation is a slightly exothermic catalytic burning of aqueous glucose, in which 49% of its mass is converted to carbon dioxide gas. The main liquid reaction product, ethanol, retains most of the free energy of the glucose (Evers, 2007).

The following diagram indicates exactly some of the inputs and outputs associated with ethanol production from corn.

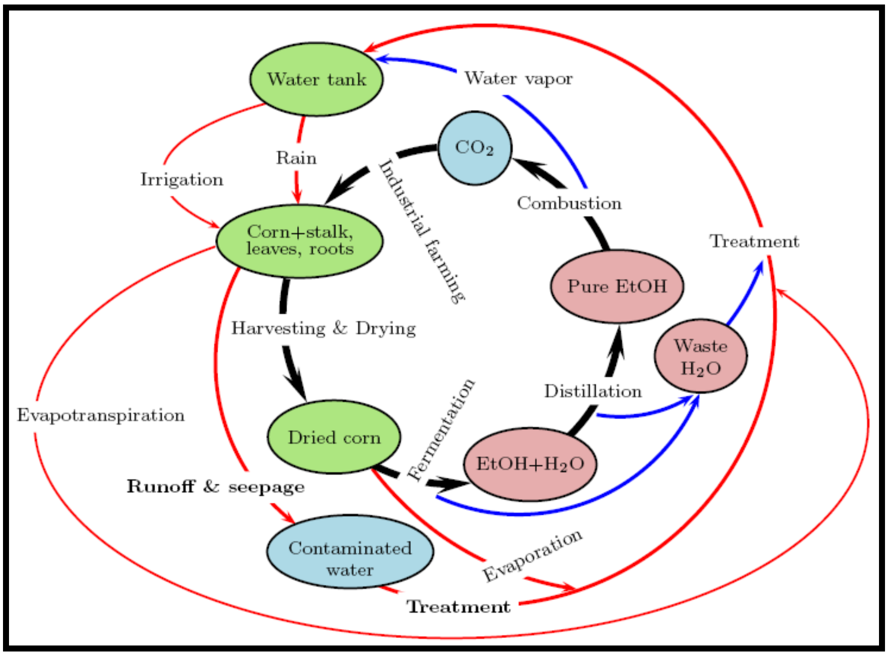

Diagram 9 - All inputs and outputs for ethanol production.

There is research being carried out in the US where the energy to produce the ethanol is created from the actual waste from within the distillation process by producing methane from the waste. An added benefit is the production of a solid waste that can be use as stock feed or fertiliser. The methane is then burned to produce the heat needed for distillation. No resource is extracted from the ground, greenhouse gas emissions are minimal. Any CO_2 present can be extracted from the methane to further reduce emissions, and a non-renewable resource can now last longer.

If the 10% ethanol scenario currently being considered in Australia[1] were to go ahead the ethanol industry would boost its economy by selling 0.18 billion litres of ethanol for a total of $2.16 Billion.

Let us assume that the research provides positive answers. We will expect something like the following. When one considers the triple bottom line of this the savings are quite substantial. When one considers the cost effectiveness of being able to produce a litre of ethanol for a lot less than previously by utilising the resources recovered and clean energy generated from the process waste (to use back in the process or for sale off site) the savings are exceptional. When one considers the benefit to the environment (reduce CO_2 from oil extraction and use, reduction in energy inputs for corn to make ethanol, an organic fertiliser made from the corn ethanol waste is used back in the process to grow the corn) the benefits are incredible. Essentially the production of ethanol from corn can become a closed loop.

This research will quantify the total economic, environmental and societal costs and benefits of this.

[1] The Australian Government are considering making it mandatory for every litre of petrol being sold should contain 10% ethanol. At present customers are allowed to choose whether they would like this option or not.

8.0 Conclusion

Environmental and social imperatives now affect the bottom line for all major corporations and projects globally. This is particularly challenging in the resources and energy sectors. All businesses need to understand and efficiently optimise their operations in the context of ecology and society in addition to their obligations of profitable operation.

One of the key characteristics of environmental economics is the capacity to widen the perspective of consideration, particularly in the identification and selection phases of project development, expanding the decision window materially in terms of the range of issues, impacts and timeframes considered. Under such consideration, the decision 'window' for projects inevitably moves out to the future and discounts rates are inevitably reduced.

Environmental economics is a detailed whole life-cycle economic cost benefit analysis, which places dollar-values on external environmental and social impacts and risks, to provide a far broader view of project sustainability, in hard financial and economic terms. This allows various sustainability options and objectives to be compared using a common unit of measure (money). The risk-assessment results form the basis for identifying and monetising the external assets at risk. Thus proving a much wider and more comprehensive picture of the true economics of each option, and their real relative contributions to sustainability. Decision-making is radically improved, and decision-makers are provided with quantitative clarity in an area that was previously qualitative and indeterminate.

The production of corn based ethanol has many advocates and many critics. Believers have decided that ethanol is essential for future energy consumption, other alternatives need to be researched and found, and climate change is happening and must certainly be reversed.

Some non-believers are adamant that climate change is not happening. Others believe ethanol from corn will reduce food for humans and ultimately will not solve the energy crisis. The reduction of is a very valid issue and on-going research into alternative ethanol producing crops is certainly needed. However, is the issue of climate change, whether it is true or false, here or not here, in any way relevant? Should we not look into alternatives as a matter of economics anyway? Oil reserves are dwindling rapidly, alternatives need to be found.

In modern day environmental management, the principles of environmental economics is essential. It is a way of counting the true cost of a product. Sustainability principles require us to endorse a zero discount rate. We cannot survive economically without caring for the eco-systems with which we rely on for so much.

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