University of Southern Queensland

Faculty of Engineering and Surveying

Improve waste recycling potential through the conversion of normal household waste into biogas.

A dissertation submitted by

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In fulfilment of the requirements of

Courses ENG4111 and ENG4112 Research Project

Towards the degree of

Bachelor of Engineering (Civil)

Submitted: 5th January 2010

"Waste not the smallest thing created, for grains of sand make mountains, and atoms infinity."

-E. Knight

ABSTRACT

Waste not, want not. This age old adage will be familiar, and most probably held as true, by a large portion of today's modern society. Yet we live in what is unquestionably the most wasteful culture that has ever existed. A change in mindset is required. As a society we need to realise that we should be minimising waste, rather than simply creating more. Unfortunately it is often seen as 'too much' effort, or simply not 'cost effective' to do the right thing.

This project aims to investigate the potential for small scale biogas production by anaerobic digestion, in order to increase self sufficiency and minimise waste produced in developed society. Practical tests in scale model digesters to determine the biogas potential of different waste products were undertaken. A design for a self contained and easily mass producible biogas system, using only the waste products from a typical household, was then designed.

The purpose of the project is to illustrate that operating a biogas digester need not be associated with 'too much' effort or excessive cost. It will be aimed at creating a design for a system that will be reasonably self maintaining and robust enough to operate through varied treatment and environmental situations. The target end user will be one with little technical knowledge, understanding of biogas, or specific expertise.

The energy saved by recycling one aluminium can equals the amount of energy it takes to run a TV set for four hours. This is the energy equivalent of 1.9 litres of petrol. It takes 4,086 kilograms of bauxite and 463 kilograms of petroleum coke to manufacture one ton of aluminium. Using recycled aluminium reduces raw material requirements by 95 percent and energy requirements by 90 percent.

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CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution except where specifically stated.

Mark Dennis Cooper

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ACKNOWLEDGEMENTS

This research was carried out under the principal supervision of Dr. Talal Yusaf.

Appreciation is also due to Prof. Asso Armando Apan

This is quite possibly the only chance I will ever have to publically thank those in my life that mean the most to me, so I want to make the very most of the opportunity. All of you in some way or another have contributed to who I am and hence either directly or indirectly, my work in this dissertation.

I want to thank my beautiful, wonderful wife Daniela for all your support and patience while I complained about how much work I had to do. I'm sorry about all the times I was late for dinner and the long lonely nights I spent tinkering on this in the shed and in front of the computer. To my mother Mona, for all of your motherly wisdom that helped me keep my feet on the ground and head the right way up. You helped me to keep my priorities on the things of eternal value and not get lost down here in the details. To my Father, Dennis, I miss you every day. I will keep giving my all with my vision set firmly on the prize like you taught me, I am who I am because of you. Heinz and Heidi, my new parents, thanks for the constant support and encouragement to persevere to the end. Carla and Luke, I miss you guys, wherever you are feels like home to me (Ps I will replace the chocolate!). Amy my gorgeous sister, keeping the boys away from you is a full time job that may very well be the death of me, I can't wait to chill together soon. All my new brothers and sisters, you have made me feel right at home in your wonderful family, I love you all. My grandparents Maher and Margaret, Ruben and Olga who made untold sacrifices that gave me the opportunity to be where I am today. Tom, Allison, Emily and Jeff, you guys da' Bomb! To Scotty and Gunners the brothers I never had. Thanks for all the goat fishing and boat dropping. May the stupidity never cease.

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NOMENCLATURE, ACRONYMS AND ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
BTU	British Thermal Units
CNG	Compressed Natural Gas
CSO	Combined Sewer Overflow
EPA	Environmental Protection Agency
ETS	Emissions Trading Scheme
GDP	Gross Domestic Product
LPG	Liquefied Petroleum Gas
SSO	Sanitary Sewer Overflow
WHO	World Health Organisation

CONVERSIONS, CALCULATIONS AND UNITS

Units

J	joule
L	litre
t	tonne
g	gram
W	watt
Wh	watt-hour
b	billion (10^9)

Metric prefixes

k	kilo	10^3 (thousand)
M	mega	10^6 (million)
G	giga	10^9 (1000 million)
T	tera	10^{12}
P	peta	10^{15}
E	exa	10^{18}

Other abbreviations

bcm	billion cubic metres
m^3	cubic metre
bbl	barrel
Mtoe	million tonnes of oil equivalent
na	not available
pa	per annum

Conversion factors

1 barrel = 158.987 L

1 kWh = 3600 kJ

1 MBTU = 1055 MJ (BTU = British Thermal Unit)

1 m^3 = 35.515 cubic feet

1 L propane liquid = 0.272m^3 gas

1 L butane liquid = 0.235 m^3 gas

1 L LNG = 0.625 m^3 natural gas

Indicative energy contents of fuels are listed at the end of the publication.

Conventions used in tables and figures

0.0 is used to denote a negligible amount. Small discrepancies in totals are generally the result of the rounding of components.

Care should be taken in comparing data across tables as sources and time periods may vary.

Figure 0-1: Table from ABARE 2009

1. INTRODUCTION

"You would hope that people see what needs to be done. It's not rocket science. It's not difficult. It's not even all that costly. It's actually the way you think about the world."

-Tim Flannery

1.1. OUTLINE

The above statement suggests the need for humankind to re-think what they hold as true. As a general rule democratically elected governments worldwide will attempt to make decisions that do not stray too far from the reality of public opinion. Otherwise it stands to reason that they will not stay government for long. This indicates that as much as people blame their elected officials for policy decisions, the real decision has been made by how the majority of their society perceives the issue. It is therefore up to society as a whole to change the way it thinks about its environment and lifestyle choices. A goal of this study is to be a vehicle for that change. For this very reason the language used in this report is aimed to be more personally engaging and potentially less formal than the standard dissertation language. If it is to achieve its aim in causing people to think about issues that have previously be held as status quo, then people must want to, and even enjoy, reading it or it obviously cannot have the desired effect.

The author has had a personal interest the field of waste reduction, particularly through biogas production, for a number of years, and hopes to challenge one of societies commonly held beliefs. This belief is centred on the thoughts, 'I cannot solve the problem', 'one person cannot instigate a global change', or 'it's not personally beneficial or within the realms of my ability to make a difference'. This report intends to prove that a person with no scientific or technical background can maintain the function of a biogas digester and reap the rewards of reusing waste and saving valuable resources. To design a digester that essentially looks after itself and provides John McNormalguy with reliable energy at the same time as reducing his waste output is the ultimate purpose of this project, but on a larger scale, is merely a step toward much more significant goals.

There have been hundreds, if not thousands, of studies into biogas published and also available on the internet. The goal here is not to replicate studies into gas molarities, pH levels, heavy metal concentration, efficiency, sulphides, ammonia, phosphorus and dissolved oxygen levels, the carbon to nitrogen ratio, or any other inherently technical subject area. There will be no endless pages of tables and data, the main questions asked will be, does it work, is it safe, is it easily maintainable, and is it something the wider community would need, or more specifically, want? Any tests or observable outcomes that cannot be measured by the end user are given a secondary priority.

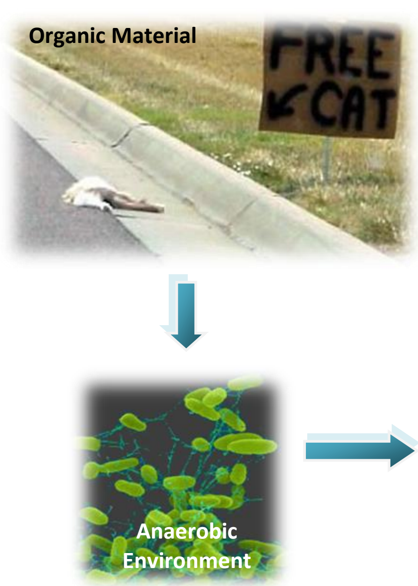
1.2. WHAT IS BIOGAS?

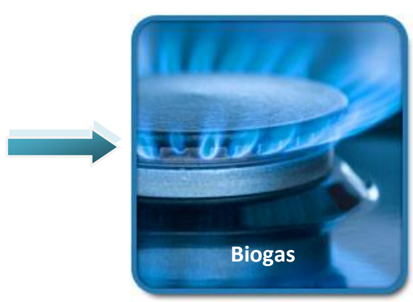
Biogas is a combustible gas that is comprised mainly of methane and carbon dioxide. It is created through a process called anaerobic digestion where certain bacteria degrade biological material in the absence of oxygen. It is a renewable energy source that can be produced using almost any biological material as a feedstock. Also going by other names such as swamp, marsh, and landfill gas, this naturally occurring gaseous product is an essential part of the biogeochemical and carbon cycles. Houweling et al. (1999) estimates that somewhere in the vicinity of 600 million tonnes of methane is released into the atmosphere annually through microbial action.

Table 1.1: Global atmospheric methane emissions (teragrams per year)

Origin	CH_4 Emission		
	Mass (Tg/a)	Type (%/a)	Total (%/a)
Natural Emissions			
Wetlands (incl. Rice agriculture)	225	83	37
Termites	20	7	3
Ocean	15	6	3
Hydrates	10	4	2
Natural Total	270	100	45
Anthropogenic Emissions			
Energy	110	33	18
Landfills	40	12	7
Ruminants (Livestock)	115	35	19
Waste treatment	25	8	4
Biomass burning	40	12	7
Anthropogenic Total	330	100	55
Sinks			
Soils	-30	-5	-5
Tropospheric OH	-510	-88	-85
Stratospheric loss	-40	-7	-7
Sink Total	-580	-100	-97
Emissions + Sinks			
Imbalance (trend)	+20	~2.78 Tg/ppb	+7.19 ppb/a

1.2.1 Anaerobic Digestion





Also referred to as Methanogenesis or biomethanation, this stepwise process takes place in virtually any environment where there is an absence of oxygen and a surplus of decaying organic material. It occurs in swamps, landfills, septic tanks, human and animal digestive systems, and many other, both liquid and solid, environments. Although the process is caused a range of different bacteria, there are three different groups of methanogens or methanogenic bacteria of particular interest. three groups are each, to extents, relatively environmentally sensitive.

These bacteria are one of the final steps in the carbon cycle when decomposing organic carbon and returning it to the environment. The overall biochemistry of biomethanation is rather complex, but can be broken down into a number of discrete processes.

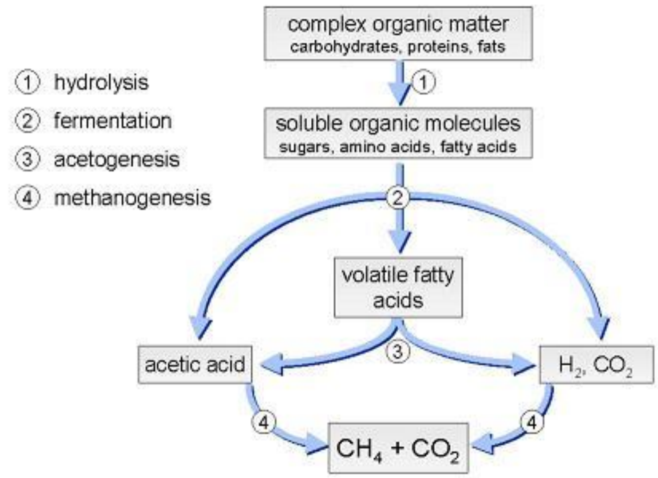


Figure 1-1: Stages of anaerobic digestion

The symbiosis of the following system should be specifically mentioned as it is a good analogy for what this project is trying to emphasise. Neither the acid forming nor methane forming bacteria can exist on their own anywhere near as successfully and effectively than when they coexist together. The environment created by the acidogenic bacteria is the ideal setting for the growth of the methanogenic bacteria. That is, all the oxygen has been consumed (anaerobic environment) and the waste products from the acidogenic bacteria are compounds of low molecular weight (perfect food for the methanogens). Alternatively, without the methanogens consuming the wastes of the acidogens, the environment would very quickly become toxic for the acid forming bacteria. In the same way that these bacteria co-exist so should the human race aim to exist in its surroundings.

1.2.1.1 Hydrolysis

This is the first stage in the anaerobic digestion process, and is involves the bacterial consumption of the original substrate. This process breaks down proteins, lipids, complex carbohydrates, and other insoluble long chain organic polymers into their component parts so that the other bacteria can access the energy potential.

This process is essential as the methanogenic bacteria cannot digest the long chain polymers and instead require the sugars, fatty acids and amino acids that hydrolysis provides. In some situations, depending on the food source, this step is less essential as there are less initial organic polymers to start with. Some of the products of this first stage, such as hydrogen and acetate can be used directly by the final stage methanogenic bacteria.

1.2.1.2 Acidogenesis or Fermentation

This second stage process involves the continued breakdown of the substrate into useful components. The acidogenic bacteria break down the products of hydrolysis into ammonia, carbon dioxide, and hydrogen sulphide, as well as other products including volatile fatty acids.

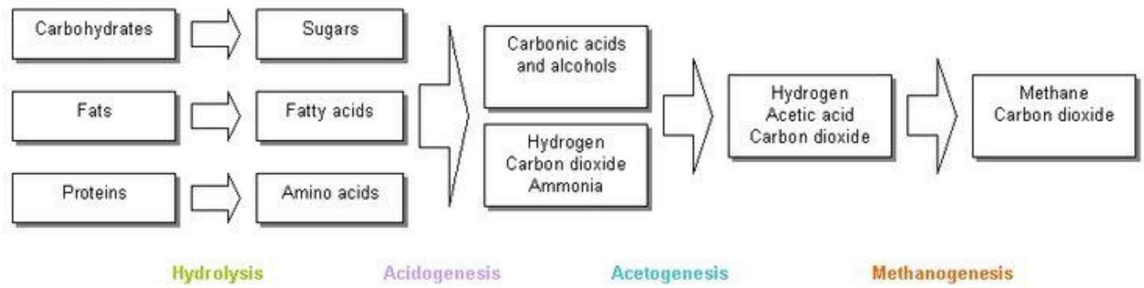


Figure 1-1: Products of anaerobic digestion

1.2.1.3 Acetogenesis

The final stage before Methanogenesis, Acetogenesis involves the breakdown of simple molecules and creation of carbon dioxide, hydrogen and acetic acid.

1.2.1.4 Methanogenesis

In this, the final stage of the entire process, methanogenic bacteria are involved in the formation of methane, carbon dioxide, and water from carbon dioxide, hydrogen and acetic acid. This step is somewhat temperature and pH sensitive and can often be the limiting step in the anaerobic digestion process. The chemical equations are as follows:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2H_2O$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$

The actual species of bacteria that is present at each stage, most particularly during Methanogenesis, is dependent on the temperature at which the digestion is taking place. There are three relevant families of bacteria.

Psychrophilic – Exists in temperature ranges below 20°C, they have the slowest rate of gas production. It is however possible to produce biogas at temperatures down even to 10°C, the rate is up to four times slower than the mesophilic. They are however very stable and less temperature sensitive than thermophilic strains.

Mesophilic – Exists in temperature ranges roughly between 20°C to 40°C. Because of the temperature sensitivity of the thermophilic strain of bacteria, this temperature range is the traditional temperature at which biogas digesters are designed to run. The bacterial population is seen to be much more robust and hence a stable supply of gas is expected.

Thermophilic - The temperature range for thermophilic bacteria is roughly anywhere from 40°C to 75°C. This type of bacteria is considered to be less stable and more sensitive to environmental fluctuations than the other strains of bacteria, however the rate of yield due to the increased temperature and reaction rates is highly desirable. This requires more energy input to maintain the required temperature, but it decreases both the retention time for maximum gas output and the time for eradication of pathogens significantly. The increase in energy input required is not usually outweighed by a total increase in output, but rather an increase in the rate.

It is important to note that the temperature ranges for the above types of bacteria are indicated as 'roughly' because it is not a clear boundary, but rather a vague temperature at which one species comes to outgrow another. It is an overlapping range, and not uncommon for all three families to be present in the digestate depending on the temperature.

1.2.2 Chemical composition

Table 1.2: Composition of biogas

Typical composition of biogas[9]		
Compound	**Chem**	**%**
Methane	**CH_4**	50-75
Carbon dioxide	**CO_2**	25-50
Nitrogen	**N_2**	0-10
Hydrogen	**H_2**	0-1
Hydrogen sulphide	**H_2S**	0-3
Oxygen	**O_2**	0-2

The specific chemical composition of an individual sample of biogas has an inherent variability. This variability is dependent on a number of different factors, from the kind of substrate, the liquid to solid ratio, temperature, pressure and other factors.

The main two gasses present are methane and carbon dioxide with the total other gasses present generally making up between one and five percent by volume.

Biogas is combustible in its natural form, and hence is usable without any form of processing, but a number of processes are still desirable. Scrubbing to remove the CO_2 increases the Btu of the gas and its calorific content. Also the removal of the H_2S is beneficial as Hydrogen Sulphide is an extremely corrosive gas that is also dangerous to human wellbeing.

Natural biogas has a calorific value of approximately 6kWh per m^3, which is 600 Btu per ft^3 approximately the equivalent of around half a litre of diesel oil.

1.2.3 Methane and global warming

Ask almost any person about greenhouse gasses and they will automatically think of CO^2. The media has formed public opinion to the extent that, in most people's perspective, CO^2 is the only substantial greenhouse gas. This is not necessarily the case. Mohr (2005) p.2 states that nearly half of the planets anthropogenic global warming effect is due to methane. These greenhouse gas and global warming studies are obviously highly unverifiable, but quite a few different studies have put the number somewhere between 28% and 40%. These studies are not particularly relevant to this report and hence are not referenced in detail. What needs to be taken from this is that methane plays a large role, much larger than previously thought, in the global climate. Although the is a much higher concentration of carbon dioxide in the atmosphere, methane is a 21 times more powerful greenhouse gas, and has risen around 200% since pre industrial times. The main cause for this increase in methane is the animal agriculture industry. Now a lot of people are suggesting the solution that we all become vegetarians, but the author loves a good steak as much as the next guy and is not sure that this would be a popular resolution.

The manure that is produced in feedlots, piggeries, dairies and other intensive animal agriculture undergoes, because of its physical situation, a combination of aerobic and anaerobic digestion. Aerobic digestion produces mostly carbon dioxide while, as discussed, anaerobic digestion creates mostly methane. Both of these sources of anthropogenic greenhouse gas are controllable by utilisation of biogas generation, and with a net energy gain as well.

1.2.4 History of biogas

Biogas has been in use by mankind for many thousands of years. The ancient Persians as well as Egyptians and Chinese all used some form of anaerobic digestion of waste to create heat and light. It is not a new invention, simply a copy of a natural process. In more modern times, around the mid to late nineteenth century, biogas generation began to become significantly more popular in countries such as India and China. Also after the world wars this form of energy generation was essential for war ravaged Germany to be self sufficient in its energy requirements.

1.2.5 Utilisation

There are many applications for biogas. Natural gas (methane) is already widely used in society and once scrubbed free of impurities biogas is the chemically almost identical. Anywhere that natural gas is used, so to biogas. In a number of nations worldwide it is possible for a small scale biogas generator to pump back into the grid the same as electricity. Natural gas or biogas also has a large potential market in power generation and as a vehicle fuel.
In developing nations the ability to generate your own energy has had a huge impact on the standard of living. It has reduced the workload of some people, particularly women, up to three hours per day, along with decreasing levels of respiratory illness from no longer having to burning animal wood and animal manure. Further investigation into the progress of biogas in developing nations is outside the scope of this study.

Table 1.3: Biogas equivalent

Application	$1m^3$ biogas equivalent
Lighting	equal to 60 -100 watt bulb for 6 hours
Cooking	can cook 3 meals for a family of 5 - 6
Fuel replacement	0.7 kg of petrol
Shaft power	can run a one horse power motor for 2 hours
Electricity generation	can generate 1.25 kilowatt hours of electricity

1.2.6 Benefits of biogas

- Methane fuel produced;
- Nutrient rich slurry makes excellent fertilizer;
- Removal of pathogenic materials;
- Financial income;
- Carbon trading potential;
- Carbon neutral process;
- Decentralised energy production means less energy lost in transmission;
- More individual and community capacity and responsibility to fight climate change; and
- Less conventional energy sources required.

As discussed in section 1.2.3, biogas generation has the ability to capture and reduce carbon dioxide and methane emissions from certain animal agriculture applications. The energy created from all biogas is also completely, in a relative sense, carbon neutral. Now the generation apparatus itself obviously has some form of carbon cost, but so does the equipment used to generate the energy and process the waste that the biogas system is replacing. When these reductions in requirements of centralised energy production are offset by the carbon cost in creating the digester, there would be little difference in carbon debt.

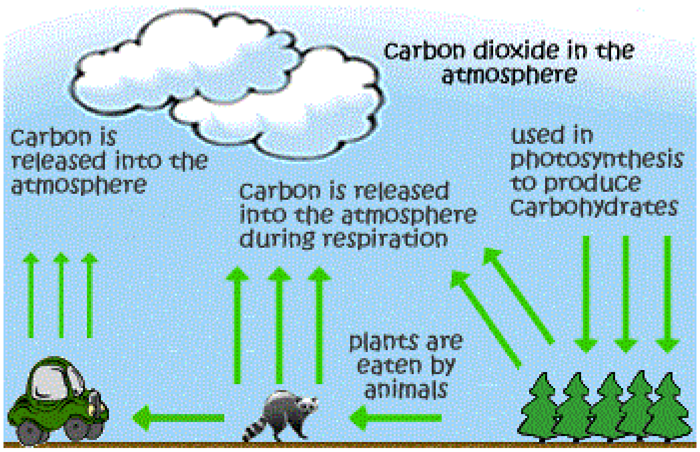


Figure 1-2: Non carbon-sink depleting carbon cycle.

The combustion of the gas itself and the resulting work done and carbon dioxide and water vapour created is in itself a carbon neutral process. The gasses released are ones that were removed from the atmosphere to begin through plant respiration and is a part of the natural carbon cycle. There is no carbon being removed from storage and placed into the active system. Logic states that if no carbon is removed from storage (i.e. dug up from underground, removed from the soil, or from cutting down forests) the amount of carbon in the system, regardless of human activity, could not increase. Recycling energy in this way is an excellent solution to the problem of global warming.

The United Nations Development Programme Report, Energy After Rio: Prospects and Challenges (UNDP 1997) listed biogas as;

"One of the most useful decentralized sources of energy supply."

"Unlike the centralized energy supply technologies, such as power plants based on hydroelectricity, coal, oil or natural gas, that have hitherto been the only choices open to rural communities, biogas plants do not require big capital to set up, and do not pose environmental problems that excite public opposition. Instead, in most cases, they offer solutions to existing environmental problems, and many unexpected benefits besides."

Another point to note, though not specifically relevant in the context of this report, is that in the year 2000 between 1.5 and 2 million deaths were the result of indoor air pollution from burning solid fuels (Ezzati and Kammen, 2000). This is around 4% of total mortality statistics worldwide. This is a staggering figure that need not be a reality.

1.3. DEFINING WASTE

1.3.1 Waste production is a necessary function for all living organisms.

All levels of life from single celled creatures to entire human societies operate on the principle that they will intake nutrients and export waste's as required. For almost all creatures that includes in-taking some form of carbon or other energy source and discarding the by-products of their energy reaction. With humans on the other hand, this equation becomes much more complex. To 'survive' we need our Audi's, fast food, Nintendo Wii's, and if you don't mind collecting my dry cleaning and rubbish on Wednesday, that would be tops. Our race has developed past essential needs and simple wastes to a complex web of inputs and outputs that even the most casual of observer would notice will be difficult to maintain indefinitely.

Figure 1-3: Using landfill is not a sustainable practice.

The levels of toxicity that will be harmful for the ecosystem itself do not necessarily coincide with the levels that will be detrimental for human health. In many cases the level of damage to a system becomes irreparable before any noticeable impact upon human wellbeing is suspected.

1.3.2 Every ecosystem has the ability to process or store wastes.

The very survival or life depends on its environments ability to detoxify itself over a period of time. When this rate of detoxification is exceeded by the rate of waste production the system is not in equilibrium and hence is not sustainable. Just as different ecosystems have varying ability to maintain balance, they also have varying flexibility to accumulate unprocessed waste. The planet Earth for example is storing Carbon Dioxide gas in the atmosphere as a result of the increase in production from human activity over the past century. As the capacity for storage in a non-equilibrium system decreases then the environment become more and more toxic and less conducive for life. A simple illustration from basic biology is to insert bacteria into a nutrient rich medium then observe the growth rates. The bacteria will initially grow and reproduce rapidly but as the waste products from bacterial metabolism begin to collect in the culture, the bacteria will eventually poison themselves and die. At this stage there is still ample food for the bacteria, they can simply no longer exist in the toxic environment.

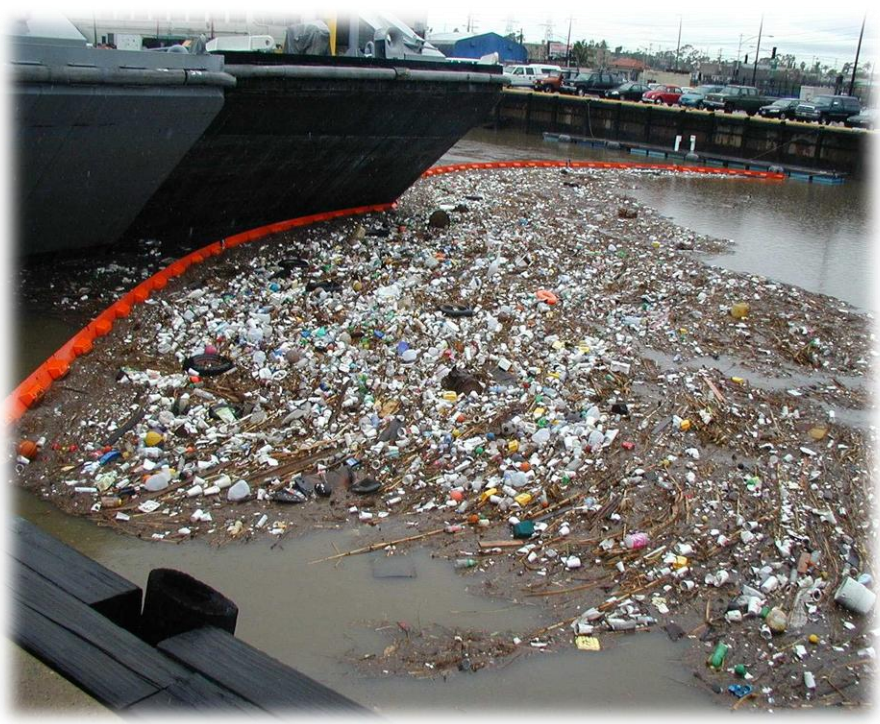


Figure 1-4: Dumping waste at sea is not a sustainable practice.

Historically in human society, the 'out of sight, out of mind' practice of waste disposal has been prevalent. Dumping waste at sea, covering it in landfill or even transporting it elsewhere have been methods that most societies have employed and continue to employ. This isn't, and has never been, a long term solution.

1.3.3 Waste in a human context is a function of a number of factors.

Factors such as population size, government choices, affluence, and popular opinion. For example the population level will be almost directly proportional to the level of sewage waste produced, while the composition will vary slightly with the nutrition status of the population.

1.3.4 The other kind of waste.

Another context in which the word 'waste' can be used is just as relevant in this paper. That is, when a by-product is not 'a waste' but rather 'wasted', or not having its potential fully utilised. In a natural food chain or cycle, every by-product is exploited or even crucial to another species survival. For example the ammonia released during a living creatures death and subsequent decay is cycled through the soil by certain bacteria then taken into plants to be reinserted into the food chain and hence continue the cycle. Humans on the other hand operate outside this structure and create vast amounts of unused by-product. To be fully in equilibrium with the Planet Earth's environment, and hence not toxifying ourselves out of somewhere to live, these wasted resources must be harnessed and in doing so, minimised.

1.3.5 Waste on a micro rather than macro scale.

This study is focused on minimizing waste and improving the reuse of resources on an individual household level rather than on an industrial or national level. In light of which the main areas of interest is the processing of relatively low toxicity, domestic organic wastes rather than those with high levels of chemical contaminants. These wastes include two main areas namely, sewage, and food preparation wastes.

1.3.6 Sewage.

A large amount of energy is used to process sewage. Treatment plants use on average 50kWh per head of population annually, and often comprises the greatest use of electricity by local government. Because the vast majority of this energy comes from coal fired plants, waste production is far from carbon neutral.

Figure 1-5: Many countries dispose of sewage directly into the ocean.

In relation to human health, the management of this solid waste is an extremely important function. In the vast majority of developing nations almost all the wastewater is discharged with only the barest, if any, treatment. Some nations inject it directly into the groundwater, while others release it untreated into the rivers and oceans. This strongly encourages the propagation of numerous deadly pathogens such as, typhoid, shigella, cholera and viruses, causing diseases such as polio, diarrhoea, meningitis, and hepatitis. Sobering estimates state somewhere in the region of 1.6 to 2.2 million children die annually from waterborne disease. Another estimate places the number at 12 million adults and children who die from lack of suitable waste treatment. Even in so-called developed countries like the United States there is a significant amount of untreated sewage released into the environment. The EPA in 2008 estimated that there was somewhere in the vicinity of 40,000 SSO events in the US annually. Older cities in Europe and Asia have an even higher level of CSO and SSO events because of their ageing sewer systems.

Figure 1-6: Results of overflow event.

As well as the devastating human cost these discharges of wastes into the environment can take their economic, social, and ecological toll as well. Fish kills, restriction on certain commercial seafood industries, turbidity, the lack of dissolved oxygen, beach closures and restricted swimming are other results of SSO and CSO events. In US coastal waters approximately 15% of commercially viable shellfish plots are un-harvestable because of pathogen contamination.

The financial cost of sewerage treatment in many cities exceeds other costs such as police and fire services. The EPA in 1998 stated that it would need $32.9 Billion to remediate the, then listed, 5,664 contaminated sites. Their estimate to improve municipal waste collection systems to a level of one in five year overflows would cost $98 Billion. As increased urbanization, in mostly coastal regions, occurs then the septic treatment process of these dense population centres will balloon and it can be seen now how poorly the world’s so called mega-cities waste treatment plants are falling behind.

1.3.7 Food waste.

Most people would not think that throwing out their food scraps as a waste, after all, they will only rot back into organic carbon and soil in landfill. Upon closer examination though, it seems obvious that what we eat arrives at our door with a carbon debt. Yes it's true. Your apple cores aren't carbon neutral, neither are the potato peelings, and certainly not your cornflakes. All the trucks used to get them to you, processing and packaging, refrigeration, and even the hot water used to wash your dishes after eating. All of these processes are, in essence, digging up inert and stored carbon and releasing it into the atmosphere. When viewed in this perspective it seems a certain waste not to fully utilize the full potential of leftover food. Yes, your veggies owe you a great deal.

1.4. THE PROBLEM

As mentioned above, the world as a whole, and individual societies within, have an attitude problem regarding waste production and processing. Biogas generation is a relatively simple and efficient method of waste reduction and energy generation that has been extensively implemented in numerous developing nations. What is impeding its further application and growth in the so-called developed nations?

Germany, for example, is the developed world's leader in biogas development. This is mainly an after-effect of world war two and the post war era where energy was in short supply, and national self sufficiency was paramount. There are an estimated 4000 biogas digesters in Germany today which create approximately 42 million m^3 of biogas per annum (Renewable 2007, Global Status Report, REN21 2007 p.33). The majority of plants are large scale industrial plants, but has the capacity for individual users to feed gas back into the grid with a generous tariff scheme.

Compare this to China, the world's clear leader in biogas generation. Currently there are over 20 million digesters creating over 9 billion (10^9) m^3 of biogas annually (Renewable 2007, Global Status Report, REN21 2007 p.33). This is predicted by 2020 to have reached 25 billion m^3, and a further 60 billion by 2030. This energy source provides for the entire energy consumption for 25% of China's rural population.

Of the 25 million households worldwide that derive their energy for cooking and lighting from biogas generators, 20 million, as mentioned, are in China. There are a further 3.9 million in India and 150,000 in Nepal. Sri Lanka, Colombia, Ethiopia, Tanzania, Cambodia and Bangladesh are also significant users of Biogas Technology.

There is quite obviously seems to be a difference in the attitude of the populations of various countries and societies toward biogas. More specifically there appears to be an attitude difference between developed and developing nations.

Could it be because of;

- The population difference?
- Differing energy requirements?
- Economic viability?
- Environmental differences?
- Social perceptions?
- Mis-education?
- Is it all just too hard?
- Or are we (developed world societies) all too lazy and busy?

"I mean, who wants to work with poo?

To come home from work and spend an hour fiddling with pH levels and temperature gages, never mind the unreliability. What happens when, on the cold, June long weekend when you're visiting two year old nephew commits germicide by flushing a whole bottle of disinfectant down the toilet? You've got no hot water, no heating and can't cook.

It's just all too much work.

I live in a consumerist society. I go to work to make money and pay for the goods and services I use so that I DON'T have to literally provide for myself in any way. That kind of lifestyle is for the tree hugging hippie types. I'd rather buy my groceries at the store, have my garbage taken away every week and the metaphorical leftovers disappear nicely down the toilet."

-Joe McNormalguy, 2009

1.5. RESEARCH OBJECTIVES

- Analyse different aspects and methods of biogas production;
- Determine the potential for biogas from different common household wastes;
- Determine the effect of environmental conditions on yield;
- Determine most effective method for small scale biogas production; and
- Design a suitable system to meet the following criteria:
    - Simple to construct;
    - Finds compromise between gas production and maintenance;
    - Automated process as much as possible within stipulated budget;
    - Ensures removal of all pathogenic material;
    - Simple to use;
    - Simple to maintain;
    - Safe, (both pathogenically and physically);
    - Effective;
    - Low cost;
    - Possible to mass produce; and
    - Can change so-called developed societies thinking about biogas generation.

1.6. CONCLUSIONS

Most households worldwide, regardless of physical location or affluence, do not use their resources to full potential. The sewage and food wastes are in themselves natural organic materials and as such carbon neutral, but when all the energy costs associated with producing and treating these wastes are factored in reusing them will save a lot of carbon emissions.

The term 'too much' effort has been used a number of times through the course of this report. Although this term is obviously un-definable, it is the vocabulary of choice because it indicates the variability in human nature. What may be too much effort for one is not necessarily too much for another. By defining 'too much' this way, it is indicated that the resulting design will aim to be not 'too much' effort for the average person – aka, the author.

This dissertation aims to indicate how simple it is for society to fully utilize their resources, maximise their energy potential and minimize their carbon footprint. The dilemma was clear, now all I had to do was critically analyse what was required then problem-solve like a madman.

2. LITERATURE REVIEW

"You must be the change you wish to see in the world."

-Mahatma Gandhi

2.1. INTRODUCTION

This chapter will review literature to establish the need for society to reduce waste, more specifically to reduce waste through converting it to biogas.

There are thousands of published tests and information on various biogas processes, and many types of different digesters to analyse. It is not the purpose of this project to take any previous information or assumptions and build on them to design the perfect biogas plant. The larger goal is to perceive if one very standard and unremarkable human person can make an impact on a social consciousness.

Rather than analyse many different models of digester, carefully weighing up the pros and cons of each than choosing a particular model and modifying it to suit, this project aims to design a system from scratch with the materials at hand. This approach is a necessary one with the larger goal in mind. The resulting digester is designed based on the assumption that 'less is better – as long as it looks after itself'. In order to prove how easy it actually is (in other words, NOT too 'much effort') to design and maintain a biogas system no external plans or concepts were used. All design steps taken were based on common sense or in response to a direct challenge faced. The author also did not wish to unwittingly copy a fault from another system, and the truth is designing it from the ground up was also really fun!

Hence an in depth extremely detailed literature review was not written. Immense amounts of research and study has gone into the subject matter, and added to the author's knowledge on the topic, but little of it is specifically relevant to this project aim. After detailing the development of some of the more common small scale anaerobic digesters in the past, this chapter will consider the missing pieces of existing work and attempt to illustrate how sustainable living is attainable.

2.2. CURRENT RESEARCH

2.2.1 Socio-economic factors.

There have been thousands of different biogas models designed and built over the course of human history. With the advent of readily available modern construction materials, the increasing price of traditional fuels, and the desire for more renewable energy sources, this growth has accelerated in recent times. That is it has displayed an exponential growth pattern. The driving factors for biogas production differ across the globe, depending mainly on the level of affluence of the society. Accordingly the amount of research and development on the different types of reactors is divided by geopolitical boundaries. Hollander (1992) reported that because of issues with cultural acceptability, biogas was successful only in certain areas. Lloyd-Laney (1998) noted that the proliferation of simple low cost designs has been rapid in third world, subsistence farming areas. Correspondingly Craddock (2008) confirms that the uptake of large complex systems in the first world has been increasing more rapidly than the growth of small scale individual systems. Lash and Lerner (1998) posturise that this is because it is too much effort for the average developed family to maintain a biogas system. Also Hollander (1992) goes on to indicate that this because of the perceived health and safety risks involved in working with explosive gas and pathogenic substances. The focus of this dissertation is to address this very shortfall. Can a simple yet effective and safe system be designed with relevant legislation in mind tho aid the uptake of this technology in our society?

2.2.2 Suitable Design.

There is debate over which kind of digester is suitable to fill the need for a small scale, simple yet reasonable autonomous system. Mital (1997) made the point that the batch process creates more gas per kg of feed and that a series of sequentially loaded batch processes would create the required gas as it is needed. He then later to state that if a truly consistent and automated system is required then there is no alternative to be considered other than a continuous system. This point is a main point of contention when considering this question and during the course of this dissertation both methods will be trialled on a small scale. It is anticipated from previous research and modelling that a continuous process will be selected.

2.2.3 Testing.

Matthews (2004) quotes the World Health Organisation’s (WHO) advice that human wastes should be held in the absence of oxygen for at least two months, or heated to a high temperature to guarantee the removal of dangerous pathogens and this is one particular aspect of design that must be addressed. During the process of this dissertation measuring the pathogens present in certain samples after the required two months will not be possible due to cost and time constraints.

2.2.4 Backup supply.

A typical biogas user in developed society is usually the self-sufficiency bohemian type. At the risk of generalizing they may tend to be more relaxed about issues such as running out of gas and not showering for a few days. For a biogas plant to be a possibility for the typical developed world citizen then there must be enough storage potential to avoid this happening. The other alternative would be a backup tank of Compressed Natural Gas (CNG) in case the biogas runs short, though the availability of CNG in Australia is currently very poor. The possibility of switching from Biogas to Liquefied Petroleum Gas (LPG) by changing the supply pressure rather than re-jetting all the appliances has been briefly looked at, but is outside the scope of this study.

2.3. CONCLUSIONS

The previous study into biogas utilization has not seemed to have to goal in mind to promote biogas as a genuine energy source for all. This research has crystallised to focus of this dissertation to a much more detailed point. Find out how to make waste minimization through gas generation, an appealing reality to a broader spectrum of the developed world.

3. THE FUTURE OF BIOGAS IN AUSTRALIA

3.1. ENERGY USAGE IN AUSTRALIA

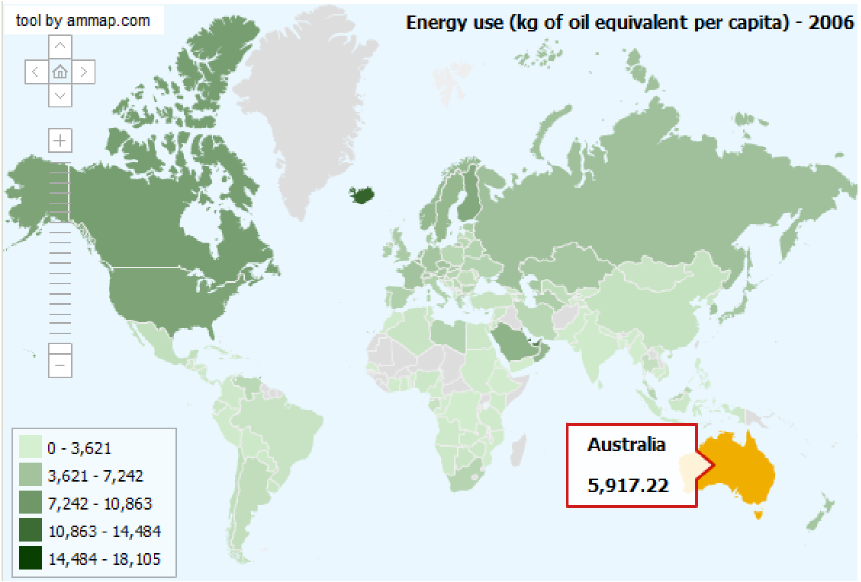


FIGURE 3.1: ENERGY USAGE PER CAPITA WORLD MAP (WORLD BANK DATA)

As a so called developed nation, Australia, or more specifically Australians, are amongst the highest users of energy per capita in the world today. This can be seen in figure 3.1 below, a graph compiled by the World Bank indicating the historical energy consumption of various nations. According to a number of recent studies, notably the CO^2 Energy Emissions Index published in the journal 'Nature Geoscience' (Nov 2009), Australians also have the rather undistinguished title of being the largest producer of CO_2 per capita amongst the world's developed nations. This is very closely related to Australia's large energy industry and exports.

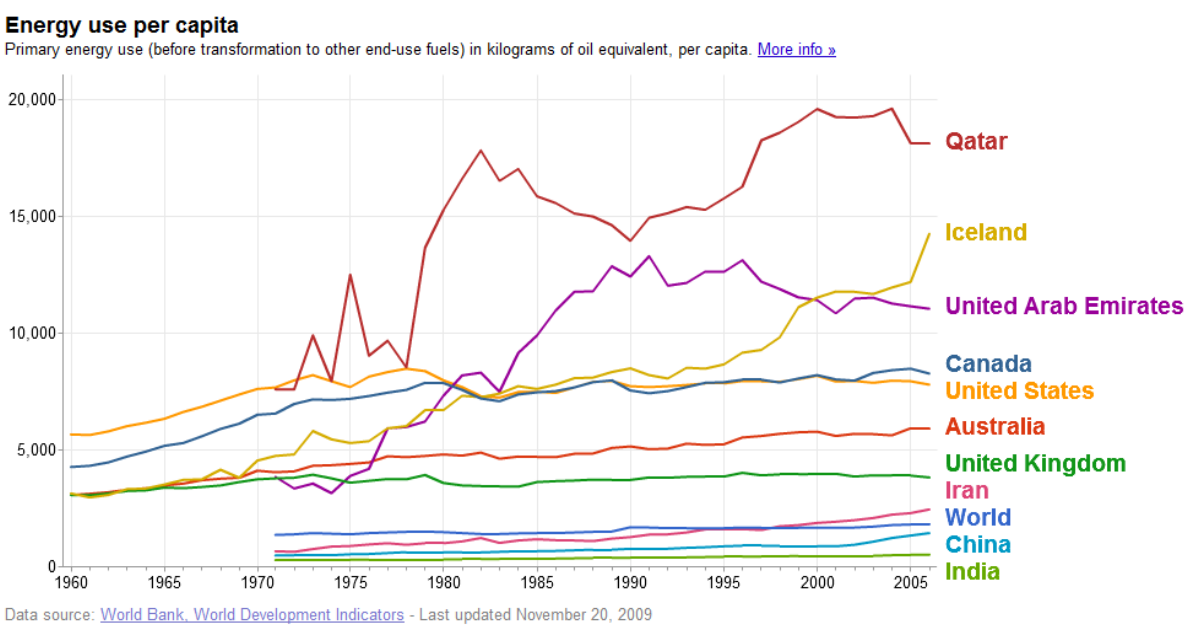


FIGURE 3-2: ENERGY USAGE PER CAPITA FOR VARIOUS COUNTRIES (WORLD BANK DATA)

3.2. ENERGY PRODUCTION IN AUSTRALIA

TABLE 3.1: PERCENTAGE GROWTH IN REVENUES 2008

1	Pipelines	27.3
2	Engineering, Construction	26.8
3	Petroleum Refining	25.2
4	Mining, Crude-Oil production	23.9
5	Oil and Gas Equipment, Services	19.8
6	Energy	16.4
7	Construction and Farm Machinery	16.1
8	Metals	16.1
9	Food Production	15.9
10	Industrial Machinery	13.3

One of the main social and environmental challenges faced by the world today is related to sustainability and global warming. This should be obvious to even the most casual of observers to worldwide media coverage. For example, the intense news media coverage and public attention (some would say frenzy) given to issues such as the pending ETS legislation and the upcoming United Nations Climate Change Conference. This also draws attention to the largest global contributor to greenhouse gas emissions, and also one of the world's fastest growing industries, the energy sector. The 2008 Fortune500 rankings (table 3.1) indicate that among the top ten fastest growing industries the first, third, fourth, fifth and sixth worldwide fastest growing industries (by revenue) are all intrinsically related to energy production.

As one of the world's largest net energy exporters, a large percentage of Australia's energy production is not for domestic consumption needs. Schultz (2009 p.1) states that in 2008 around 66% (13,559 PJ) of Australian energy production was exported and with the remaining 34% was used domestically. This equates to around $24 billion AUD in exports and $50 billion AUD in domestic consumption. Shultz also predicts that energy demand in Australia will be 50% above current levels by 2020. The global and domestic demand for energy has seen Australia's growth rate for energy production increasing steadily over the last half century. In the decade to 2008 the average growth for the energy sector was 4.3% as compared to a 3.4% average from the previous decade. The growth of energy exports on the other hand has increased by an average 7% per year in the last decade. Export earnings alone in 2007-08 jumped 15% to $43 billion AUD, and are predicted by 2010 to have jumped a further 72% to $75 billion. These huge

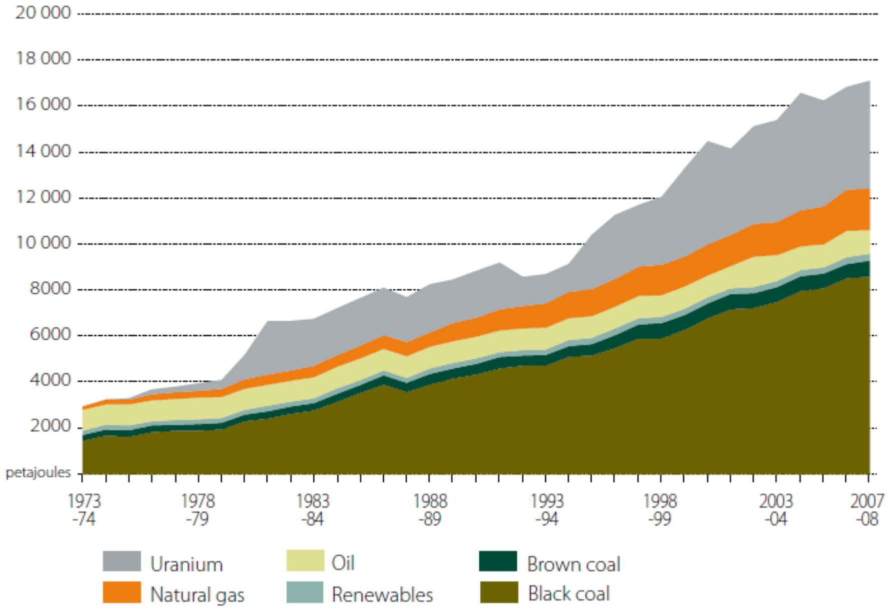


FIGURE 3-3: GROWTH OF ENERGY PRODUCTION IN AUSTRALIA

gains are predominantly driven by the unprecedented growth in export earnings attributed to coal. In 2008-09 alone the value of coal exports are up by 124% on the previous year, purely because of the increased demand and hence price.

3.3. CONVENTIONAL ENERGY RESOURCES

Because this report is focused on the production of biogas, a renewable resource, this topic will focus solely on the portion of energy production in Australia that is relevant to domestic consumption. Even if and when Australia's renewable energy production were sufficient to meet the local demand, it stands to reason that if there remains an external demand for coal or uranium or other conventional energy sources this nation would cheerfully sell it to all interested. This will undoubtedly continue till either global warming is proven to be false and because of developing technology or dwindling resources, renewable energies become more economically viable. Or when global warming is, with no uncertainty, proven to be true and the tide of public opinion and international moral social conscience demands the cessation of trade in fossil fuels. These two scenarios are clearly driven by the lust for and worship of prosperity.

TABLE3-3: ENERGY RELATED SECTORS DOMESTIC ECONOMIC PRODUCT

	industry value added A$b	gross fixed capital formation A$b	employment '000
Coal mining	16.4	5.4	26.5
Oil and gas extraction	22.4	6.5	10.2
Petroleum refining and petroleum fuel manufacturing	2.2	0.5	5.8
Electricity supply	14.6	8.5	43.9
Gas supply a	1.5	0.8	2.0
Total	57.1	21.7	88.4
Australian economy	961.9	238.5	10 436

The reason for the above statement is that Australia is extremely rich in fossil fuels, the main deposits being, coal, uranium and natural gas, and currently makes a large percentage of its

GDP by exporting them. The energy white paper from ABARE (2009) puts coal production in top spot, with 54% of total energy produced by content. Second is uranium at 26%, then natural gas at 11%. LPG and crude oil together account for 7% and finally renewable energy resources 2%.

Any data that is unreferenced in the rest of this chapter is also drawn from ABARE (2009) and for the sake of brevity has not been referenced further.

Australian energy production is obviously dominated by coal, the nation ranking fourth in the world in regards to total production, and first worldwide in exports. Australia also controls 40% of the world's reserves of low cost Uranium, and supplies 8% of the world's LNG. Natural gas reserves are estimated at around 157 343 PJ, which at 2002 production rates, is equivalent to 125 years supply. Currently identified oil reserves are noteworthy but have not grown in half a decade and are no major oil discoveries are anticipated.

Table 3.4: Energy production and usage in Australia (ABARE 2009

	Black coal	*Brown coal*	*Natural gas*	*Crude oil*	*Uranium*	*Biomass wood & bagasse*	*Solar*	*Total primary*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
				2006–07				
Agriculture	—	—	—	—	—	—	—	—
Mining	6	1	242	1	—	—	—	250
Manufacturing								
Food, Beverages, Textiles(a)	10	1	39	1	—	116	—	167
Wood, Paper, Printing(a)	12	—	21	—	—	19	—	52
Chemicals	2	8	114	1 514	—	—	—	1 638
Iron & Steel	159	—	26	—	—	—	—	185
Non-ferrous metals(a)	66	—	145	1	—	2	—	214
Other Manufacturing	30	—	80	—	—	1	—	111
Total Manufacturing	279	9	425	1 516	—	138	—	2 367
Electricity, Gas, Water	1 373	671	309	—	—	5	23	2 381
Construction	—	—	3	—	—	—	—	3
Transport								
Road	—	—	2	—	—	—	—	2
Rail	—	—	—	—	—	—	—	—
Air	—	—	—	—	—	—	—	—
Water	5	—	—	—	—	—	—	5
Total Transport	5	—	2	—	—	—	—	7
Other Services								
Wholesale & Retail Trade	—	—	15	—	—	—	—	15
Accommodation(b)	—	—	9	—	—	—	1	10
Communication(c)	1	2	10	—	—	—	—	13
Other(d)	—	1	10	—	—	—	3	14
Total Other Services	1	3	44	—	—	—	4	52
Total intermediate use	1 664	684	1 025	1 517	—	143	27	5 060
Inventory changes	43	-39	22	-60	35	—	—	1
Households	—	—	134	—	—	62	2	198
Total domestic use	1 707	645	1 181	1 457	35	205	29	5 259
Exports	6 943	—	827	594	4 474	—	—	12 838
Total primary energy use	**8 650**	**645**	**2 008**	**2 051**	**4 509**	**205**	**29**	**18 097**

— nil or rounded to zero (including null cells)
(a) Prior to 2004–05, this was included in 'Other Manufacturing'
(b) Includes Accommodation, Cafes & Restaurants
(c) Includes Communication Services, Finance & Insurance, Property & Business Services
(d) Includes Government Administration & Defence, Education, Health & Community Services, Cultural & Recreational Services, Personal & Other Services

3.4. RENEWABLE ENERGY RESOURCES

Australia has extensive solar, wind and wave renewable resources, but severely limited hydro power potential. It is commonly stated that on one hand fossil fuels are rapidly running out (justification for high prices), but on the other hand it will cost too much to convert to renewable energy. Or that renewable energy will not be able to provide enough supply to meet the world's needs. This seems to be a contradiction in terms. It is obvious that the more of a certain item produced the cheaper that item becomes relative to its production cost.

Table 3.5: Renewable Energy in Australia (ABARE 2009)

	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
	PJ	PJ	PJ	PJ	PJ	PJ
Bagasse	91.7	95.1	96.8	108.3	109.1	110.8
Other biofuels b	10.1	10.7	10.6	10.4	12.3	12.8
Hydroelectricity	57.5	58.7	58.0	56.2	57.7	52.0
Solar hot water	2.7	2.8	2.6	2.6	2.4	5.9
Wind c	0.6	1.0	1.6	3.2	6.2	22.5
Wood and woodwaste	95.0	99.2	96.9	91.5	82.3	93.8
Total	257.6	267.5	266.5	272.2	270.0	297.8

Table 3.6: Renewable Energy in Australia (SHULTZ 2009)

	PJ 2007-08	growth % 2007-08
Biogas / Biofuels	18	73.6
Hydro	43	–16.9
Solar / Wind	21	38.2
Biomass	208	2.1
Total	290	3.1

Renewable energy in Australia is maintaining its market share of energy consumption, but not growing significantly. Together biogas, solar, wind and biofuels fulfil between 1% and 3% of Australian energy consumption. (Shultz 2009). While wind energy has grown strongly over the past few years, it still only amounts for 0.4% of total usage.

3.4.1 Conversion from conventional to renewable

The Australian government, as governments are wont to do, is making significant lip service to the ideals of renewable energy, but change does not often come from the ruling party. They have introduced a measure called the Mandatory Renewable Energy Target (MRET) scheme which is designed to have increased renewable energy supply to 9,500GWh by 2010. The government has committed to ensuring that 20% of energy use comes from renewable sources by 2020.This will raise the trarget from 9,500GWh in 2010 to 45,000 GWh by 2020.

Nationwide there are 11 renewable energy projects in the stage of advanced planning and 49 more in an intermediary stage.

For a real change to take place it will require movement on the grassroots level. People demanding more renewable energy sources and paying more for it if required.

.

Table 3.7: Renewable energy

	biogas MW	bagasse MW	wood-waste MW	other renewables b MW	hydro MW	wind MW	solar MW	other c MW	total MW
NSW a	68	16	42	36	4 275	18	4.0	0.5	4 459
VIC	78	0	0	34	566	134	0.7	0.0	813
QLD	17	359	15	4	659	13	0.4	0.1	1 066
SA	22	0	10	0	5	740	0.7	0.0	778
WA	27	6	6	63	32	201	0.7	0.0	336
TAS	5	0	0	0	2 276	144	0.0	0.0	2 425
NT	1	0	0	0	0	0	1.6	0.0	3
Other d							63		63
Aust	218	380	73	137	7 814	1 249	71	1	9 942

a Includes the ACT. **b** Black liquor, crop waste, municipal waste and biodiesel. **c** Oceanwave and geothermal.
d Domestic, recreational and remote installations.
Sources: Geoscience Australia; NEMMCO; Watt, M 2007. National Survey Report of PV Power Applications in Australia.

3.5. BIOGAS POTENTIAL

One recent study in the US rates ‘cow power’ potential, biogas from cow manure, somewhere in the vicinity of 100 billion kWh whilst at the same time reduce greenhouse gas emissions by 99 million metric tons. (Dannheisser 2008)

3.5.1 Requirements for biogas

- Readily available reliable source of biodegradable material;
- Effective and economically viable storage and distribution system for gas and electricity.

3.5.2 Large Scale

This section will look specifically at the number of Sewage, Dairies, Piggeries, and barn chicken facilities there are in the nation. These were specifically chosen because of the spatially concentrated nature of the organic waste.

3.5.2.1 Dairy Cattle

In 2006 there were 2.8 million Dairy cattle in Australia (ABS yearbook 2006). This equates to a potential biogas yield of:

20600 BTU per animal per day * 2800000 * 1060 J

= 0.061 PJ per day or 2.23 PJ Annually

3.5.2.2 Swine

In 2006 there were 2.75 million swine in Australia (ABS yearbook 2006). This equates to a potential biogas yield of:

39800 BTU per animal per day * 2750000 * 1060 J

= 0.116 PJ per day or 4.23 PJ Annually

3.5.2.3 Poultry

In 2006 there were 93.6 million chickens in Australia (ABS yearbook 2006). This equates to a potential biogas yield of:

56000 BTU per animal per day * 93600000* 1060 J

= 5.55 PJ per day or 202.79 PJ Annually

3.5.2.3 Major population centres

A number of different studies (REEIN 2002) put the amount of biogas per capita from human excrement at 0.028 m^3 per capita per day.

For example Sydney, Australia's most populous city with 4.4 million would output:

4400000 * 0.028 * 365 2.81kWh = 126.36 GWh annually.

3.5.3 Small Scale

All rural properties have the potential to somewhat offset their energy usage by creating thei own biogas. The rest of this project illustrates this in depth.

3.6. CONCLUSION

These numbers are fairly significant when compared to the Australian domestic energy consumption of 18097 PJ per annum. The potential for biogas to be a part of a larger renewable energy supply is enormous. Particularly if the smaller decentralised locations that create the energy are supplying their own needs also. Less energy is lost through transmission because the electricity has significantly less distance to travel.

4. RESEARCH DESIGN AND METHODOLOGY

And Man created the plastic bag and the tin can and the plastic wrapper and the paper plate, and this was good because Man could then take his automobile and buy all his food in one place and He could save that which was good to eat in the refrigerator and throw away that which had no further use. And soon the earth was covered with plastic bags and aluminium cans and paper plates and disposable bottles and there was nowhere to sit down or walk, and Man shook his head and cried: "Look at this God-awful mess."

-Art Buchwald

4.1. INTRODUCTION

As previously mentioned, the authors interest in this subject area began long prior to its selection as a project topic. Much of the research and testing occurred previous to any mandated requirement for analytical inspection and detailed documentation and discussion of results. The decisions made were simply observation based and a natural progression of the conceptual design. During the defined period of the university project the main process undertaken has been the continual refining and implementation of the design.

Figure 4-1: An untrained person

The aim of this project is to initially create the conceptual design of a biogas digester that can be operated and maintained by an untrained person, and subsequently is not 'too much' effort to run. Although 'too much' effort is not a clearly definable term, and varies from user to user, the concept is addressed and characterised previously in this report. Because of this aim, the tests and measurements undertaken were objectively rather than quantitatively orientated. Since complex gas analysis and volumetric readings were beyond the scope of this project, and in reality, not necessary, these processes were not undertaken. Rather than aiming for a design that was potentially the most efficient, as measured quantitatively, the goal was rather a design that was the simplest to maintain that yet also achieved certain set parameters of function. The risk analysis of all practical work undertaken is in appendix B.

4.2. INITIAL DESIGN METHODOLOGY PLAN

What follows was the initial concept of what would be done. This concept was very roughly outlined some time ago before the actual practical work began.

1. Create an appropriate design for a small scale plant that is simple to maintain and build.
2. Design a measurement system for effectively logging variables such as air temperature, slurry temperature, mass of feedstock, output of gas, ph levels and other related information.
3. Build four (4) scale models of the chosen design.
   a. Four clean, pressure tested 20L chemical drums were used.
4. An equal mass of each waste was placed in the drums.
5. Each drum was treated with an equal portion of septic tank started bacteria.
6. The drums were then sealed with a small pipe inserted.
7. An extra large party balloon (up to 1000mm diameter) was attached to each pipe.
8. Run four (4) concurrent scale model tests on animal waste, human waste, vegetable waste, and a mixed composition, using animal waste as the index point of reference. Air temperature, slurry temperature, and balloon diameter were then recorded. Compare the resulting yields.
9. Research relevant health and safety standards related to septic treatment of household black and grey water.
10. Design and build a prototype septic system to Australian Standards incorporating biogas manufacture and sterile biomass output for potential commercial applications.

4.3. ACTUAL IMPLEMENTATION OF PRACTICAL METHODOLOGY

As every engineer knows, the reality of what happened when the theoretical concepts and plans were implemented can be very different from how the process was initially envisioned. The intrinsic evolution, or rather natural selection process, this undertaking has progressed through has been one based on a problem solving foundation. The following became the main central steps in this process:

1. Initial research into current knowledge levels of the topic matter was undertaken;
2. Potential desirable design features were identified;
3. Required outcomes and goals were set;
4. Initial design was finalised;
5. An initial model was built;
6. Deficiencies in the design and implementation were identified;
7. Identified deficiencies were rectified;
8. Post modification, the results were analysed and the following questions asked.

Did the resultant design:

   a. Become easier to maintain;
   b. Increase or decrease the rate of gas production; and
   c. Meet the predetermined outcomes and goals;

9. Repeat from step 6.

4.4. PROBLEM SOLVING TECHNIQUE

A biogas digester is at work every moment of every day of every year, glitches and problems are inevitable. A number of times during the course of this process an insurmountable problem (within the context of budget or ability to meet required outcomes) was faced which required that specific design development to be scrapped at the current stage and a number of steps taken backward to the drawing board. This particular 'mouse in a maze' form of problem solving was at times frustrating, but trial and error analytical methods were more suited to the problem at hand and the author's ability. I was important that the problems be solved and 'designed out' of the final model, or a simple clear procedure formulated and documented for when things go wrong. When it comes to any machine, the more complex it is, the more that can go wrong. Hence simplicity was the main target. Mother Nature was the example, to create a system as close as possible to that of a natural one, after all, it is a natural process. The design should be adjusted to fit the process, rather than the process adjusted to fit the design.

The aim was a good solid final design. There were many questions to start with, should it be a modular system for ease of problem diagnosis? Should it have secondary redundancy built in for the more foreseeable problems? It was decided to simply start building and see what eventuated. Because of the progression of the testing stages, the report is written in a logical sequential order. Something that may be overlooked at one stage in the process may be returned to and reassessed later in further development stages. This does not mean that the previous section was returned to and rewritten.

4.5. BUDGET AND MATERIALS

Living on a rural property, all sorts of scrap materials are readily at hand. Farmers seem to collect junk in case it might be useful. The main materials used were what was lying around the property, or what could be purchased cheaply from the salvage yard. Some small fittings and pipe work was purchased new, but only at last resort as the budget was very tight. The author's wife stipulated the budget very specifically as "whatever we save on groceries if you eat less food". In this manner the author had a true third world biogas experience incorporating both poverty and hunger in his effort to create energy from nothing.

4.6. TIMELINE

Because of the evolutionary nature of this design process, timelines have been difficult to predict or apply. All the testing could take place as long as there were no problems, but the design itself could not progress UNLESS there were problems.

4.7. VARIOUS WASTES COMPIRASON

4.7.1 No gas scrubbing and non temperature controlled

1kg of each horse manure, human faecal matter and vegetable waste, as well as a 3 way mixture sample was each added to a clean 20 litre chemical drum along with 9 litres of water. A large party balloon taped over the mouth of each drum, and balloon diameter was measured. An initial charge of commercially available septic tank starter bacteria was required for each drum to be on a level footing, particularly the vegetable sample, but this idea was later scrapped due to the modification in the testing parameters.

The time of year was April, and because all of the samples were exposed to the same thermal environment, no temperature controls were in place.

Figure 4-2: Initial feedstock comparison - From left to right, mixture, vegetable matter, human waste, and horse manure.

Unfortunately it seemed that the Hydrogen Sulphide vitrified the rubber in the balloons. This made this form of testing difficult over periods longer than 14 days. Two different solutions were proposed:

1. Use a different material such as a polyethylene garbage bag, or a latex prophylactic; or,
2. Filter the gas pre-measurement.

Figure 4-3: Hydrogen sulphide effect on rubber.

Option two was selected as it would give a more accurate measurement of the methane content rather that total gas volume.

At this stage, one testing setup apparatus was created rather than multiples due to the added construction requirements. This caused two changes;

1. Because the tests would not be running simultaneously, the temperature must be controlled at one set level for the duration of the testing.
2. The test samples were reduced from four to two. The human faecal matter and vegetable matter samples were dropped as the only sample of real interest was the mixture of all three. The horse manure sample was kept as a control measure.

4.7.2 Gas scrubbing and temperature controlled

This raised some interesting questions that may have relevance later in the development process.

1. How to scrub the gas – increase the methane percentage; and
2. How to maintain an optimum temperature.

Figure 4-5: CO2 Scrubber

Question one was completely relevant because the gas scrubber was a modular operation that operated independently of the main digester, whereas question two at this time was simply a case of easiest way to achieve target. The design was not even close to the final desired result, so any heating method devised in this phase would undoubtedly not be feasible or possible in the final stage.

4.7.2.1 Gas scrubber

The design for an end stage gas scrubber was somewhat of a challenge. It is possible to rather simply remove both the CO_2 and H_2S from the gas using simple everyday processes, but both of these processes require user input. The design for a self regenerating and refreshing scrubber is one that will be undertaken if time permits.

Figure 4-4: CO2 Scrubber fitting

The current design for the removal of CO_2 is simply bubbling the gas through a solution of limewater. The limewater is created by dissolving some of the considerable amount of limestone from the local area in water.

The first option considered for H2S scrubbing was a stainless steel drum filled with iron products, filings etc. A manual valve allows the iron to be recharged periodically by exposure to oxygen, this reverts the ferric sulphide back to solid iron and sulphur, but is an exothermic reaction and needs to be tightly controlled.

Figure 4-7: H2S oxidation scrubber

The current process adopted for removal of the H_2S is also very simple. The gas is forced through a pipe containing packed steel wool. This oxidation reaction with ferric oxide (rust) converts the gas into ferric sulphide and removes the majority of the hydrogen sulphide. This required the regular replacement of the steel wool. If time permits, a study into the lifespan of this steel wool product will be undertaken and comparisons made with other forms of hydrogen sulphide removal.

4.7.2.2 Temperature control.

Because of the small scale of this test it was possible to simply submerge half the digester in a body of water maintained at the required temperature.

Figure 4-7: Attempt to maintain even temperature by submergence in aquaponics tank. Author's dog supervising work. Note previous attempt at water heating with a steel bathtub and fire.

The author also has an aquaculture system in place with approximately 800 silver perch in a tank with an old solar hot water panel to raise the temperature. The pump that drives water through the panel is activated by a temperature switch set at 27°C. This was later modified to be overridden between the hours of 6PM to 8AM as it was found that the pumping of water through the solar panel in the darkness hours lowered the temperature in the tank faster than the mean dissipation of energy. Initially the digester was simply lowered into this tank, but the variability in temperature, while acceptable to the fish, was still too much for certainty in the results.

Figure 4-9: Submerged in temperature controlled bath

Figure 4-10: Slurry composition

Figure 4-8: Final rate test.

The final more successful method of temperature control involved a salvaged instant gas hot water system set up in the same way the solar system was. The temperature switch for the pump could be set at any desired temperature and the flow of water through the heater caused the gas burners to fire. This required a much more powerful pump for enough flow to activate the instant gas system so it was connected straight to the house water. This meant that the runoff could not be recycled through the system and was instead routed onto the authors budding frangipani trees for irrigation.

4.8. TEMPERATURE SENSITIVITY TEST

Using the same apparatus as the previous test, the temperature sensitivity test measured simply the rate of reaction in regards to production of methane, not biogas. The composition of the gas as well as the production rate would change as the temperature was modified, but because of the scrubbers, it was mostly the methane that was measured. This measurement was more relevant to the overall project than the total amount of gas produced,

An initial charge of 100g of mixture to 900ml of water was added to the model. A constant daily charge of 10g : 90ml was added and the temperature was maintained at 35°C until some form of consistency was noted in the daily balloon circumferences. The balloon was vented and reset every day to find the daily value rather than a cumulative value. When this equilibrium was reached, the temperature was dropped to 15°C the returned to 36°C one degree per day. The daily balloon sizes were measured.

Figure 4-11: Digital thermometer reading

4.9. CHEMICAL SENSITIVITY TEST

- An initial charge of 1kg mixture : 9L water was added to a single drum;
- This was mixed regularly over a period of 14 days;
- A daily charge of 40g : 360ml was added;
- On the 14th day the mixture was separated into 4 separate containers;
- Each was given a daily charge of 10g : 90ml along with a 10ml charge of either:
- Citric acid (orange cleaner);
- Acetic acid (vinegar);
- Chlorine (household bleach); or
- Household antibacterial disinfectant.
- The balloon circumference results were tabulated.

Unfortunately the author was called away to the East coast during this test due to his grandfathers passing away. Also the two weeks of residential school at USQ also made another attempt impossible within the required timeframe. This is one test that probably should be repeated as soon as possible. The real world testing of the design and random cleaning products has the potential to severely effect gas production and in that situation it will be significantly more difficult to pinpoint the problem to a specific product.

4.10. MODEL DESIGN

Figure 4-11: Mixing chamber

A scale model was then created to put all of this vast amount of information into practice and see if it is possible to run a biogas system with zero knowledge. Because no records were being kept of what went into the toilet, recording the balloon size every day was irrelevant. The purpose of this exercise was to leave the system to its own devices and see if there still is gas in the balloon every day and make a ballpark comparison.

Figure 4-12: Overflow and drain valve

Figure 4-14: Cordless drill and mixing bit for pre-mixing in mixing chamber

Figure 4-15: Initial design

The feedstock mixture is initially placed into the mixing chamber where the mixing process took place. The design of the mixing chamber was not intentional, but rather due to the nature of the digester tank used. The tank used was a discarded solar hot water tank, and in order to use the existing fittings, the author was required to deliver the feedstock into the tank through a standard 1” fitting. The mixing tank was required to break down the solids into a size that would fit through the pipe into the digester. The same scrubbing devices were utilised as in the previous testing and an overflow or level control fitting was added.

5. RESULTS AND DISCUSSION

“You haven't finished your milk. We can't put it back in the cow you know.”

-Mona Cooper

5.1. VARIOUS WASTE COMPARISON RESULTS

Under the initial test conditions, due to the deterioration of the rubber balloons, the time period was only fourteen days.

Table 5-1: Biogas potential comparison four samples - Balloon diameter (m).

DAY	Human	Horse	Vegetable	Mixture
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0.562	0	0	0.597
7	0.708	0.402	0	0.866
8	0.864	0.568	0.425	0.961
9	0.909	0.828	0.514	1.036
10	0	0.904	0.700	1.038
11	0	0.976	0.752	0
13	0	0	0.842	0
14	0	0	0.906	0

The balloon circumference was converted to m^3 using an online software (calculatorfreeonline.com)

Table 5-2: Biogas potential comparison four samples- Volume (m^3).

DAY	Human	Horse	Vegetable	Mixture
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0.0030	0	0	0.0036
7	0.0060	0.0011	0	0.0110
8	0.0109	0.0031	0.0013	0.0150
9	0.0127	0.0096	0.0023	0.0188
10	0	0.0125	0.0058	0.0189
11	0	0.0157	0.0072	0
13	0	0	0.0101	0
14	0	0	0.0126	0

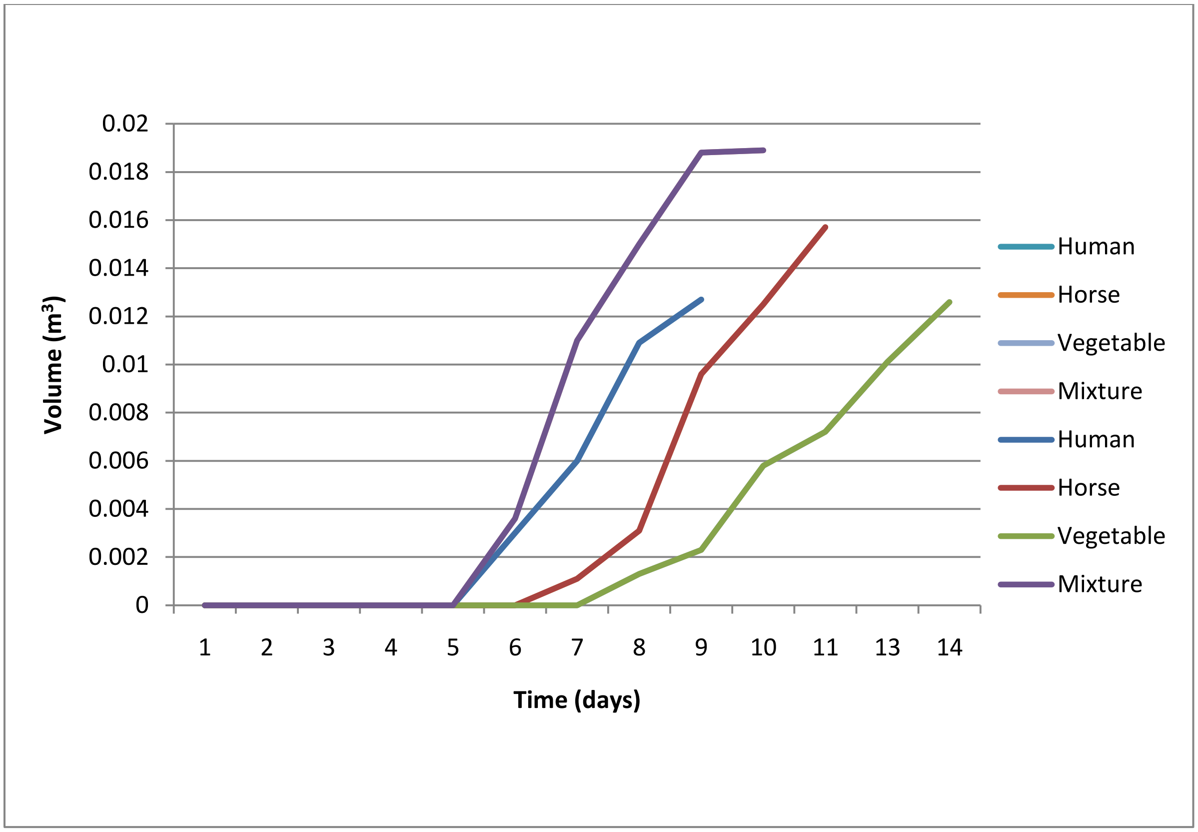


Figure 5-1: Volume and rate of biogas produced from different samples

The mixture sample was observed to have highest rate of production, but also largest variability in rate. The vegetable results are somewhat uncertain because during the initial run of this test the purely vegetable sample produced little to no gas during the 14 day period. This was remedied by adding a very small amount of commercial septic tank starter bacteria. The vegetable feedstock was the slowest producer of biogas, and also didn't appear to create as much hydrogen sulphide, as the balloon lasted longer.

The tests were completed again with only the mixture and horse manure with the digester kept at a stable 35°C and the unwanted gasses removed.

Table 5-3: Biogas potential comparison, temperature moderated - Balloon diameter (m).

DAY	Mixture	Horse
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0.568	0
6	0.652	0.376
7	0.939	0.446
8	1.002	0.586
9	1.071	0.828
10	1.090	0.914
11	1.213	0.994
12	1.238	1.025
13	1.289	1.061
14	1.339	1.111
15	1.397	1.167
16	1.475	1.209
17	1.525	1.237
18	1.560	1.261
19	1.607	1.296
20	1.664	1.311
21	1.674	1.313
22	1.687	1.322
23	1.705	1.327
24	1.708	1.334
25	1.714	1.342
26	1.717	1.352
27	1.731	1.361
28	1.734	1.363
29	1.746	1.370
30	1.747	1.375
31	1.748	1.377
32	1.753	1.380
33	1.755	1.386
34	1.758	1.390
35	1.763	1.391
36	1.765	1.397
37	1.767	1.401
38	1.769	1.402
39	1.770	1.406
40	1.771	1.408
41	1.770	1.411
42	1.771	1.414
43	1.771	1.415
44	1.772	1.417
45	1.772	1.421
46	1.774	1.424
47	1.772	1.427
48	1.772	1.429
49	1.774	1.430
50	1.774	1.432
51	1.775	1.431
52	1.776	1.429
53	1.777	1.435
54	1.779	1.435
55	1.779	1.437
56	1.781	1.441
57	1.782	1.442
58	1.781	1.444
59	1.781	1.445
60	1.782	1.450

Table 5-4: Biogas potential comparison, temperature moderated - Volume (m3).

DAY	Mixture	Horse
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0.0031	0
6	0.0047	0.0009
7	0.0140	0.0015
8	0.0170	0.0034
9	0.0208	0.0096
10	0.0219	0.0129
11	0.0302	0.0166
12	0.0321	0.0182
13	0.0362	0.0202
14	0.0406	0.0232
15	0.0461	0.0269
16	0.0542	0.0299
17	0.0599	0.0320
18	0.0642	0.0339
19	0.0701	0.0368
20	0.0779	0.0381
21	0.0793	0.0383
22	0.0812	0.0391
23	0.0837	0.0395
24	0.0842	0.0401
25	0.0851	0.0409
26	0.0855	0.0418
27	0.0876	0.0426
28	0.0881	0.0428
29	0.0900	0.0435
30	0.0901	0.0439
31	0.0903	0.0441
32	0.0911	0.0444
33	0.0914	0.0450
34	0.0919	0.0454
35	0.0926	0.0455
36	0.0929	0.0461
37	0.0932	0.0465
38	0.0936	0.0466
39	0.0938	0.0470
40	0.0939	0.0472
41	0.0938	0.0475
42	0.0939	0.0478
43	0.0939	0.0479
44	0.0940	0.0481
45	0.0941	0.0485
46	0.0943	0.0488
47	0.0941	0.0491
48	0.0941	0.0493
49	0.0943	0.0494
50	0.0943	0.0496
51	0.0945	0.0495
52	0.0947	0.0493
53	0.0948	0.0499
54	0.0951	0.0500
55	0.0952	0.0502
56	0.0954	0.0506
57	0.0957	0.0507
58	0.0955	0.0509
59	0.0955	0.0510
60	0.0957	0.0515

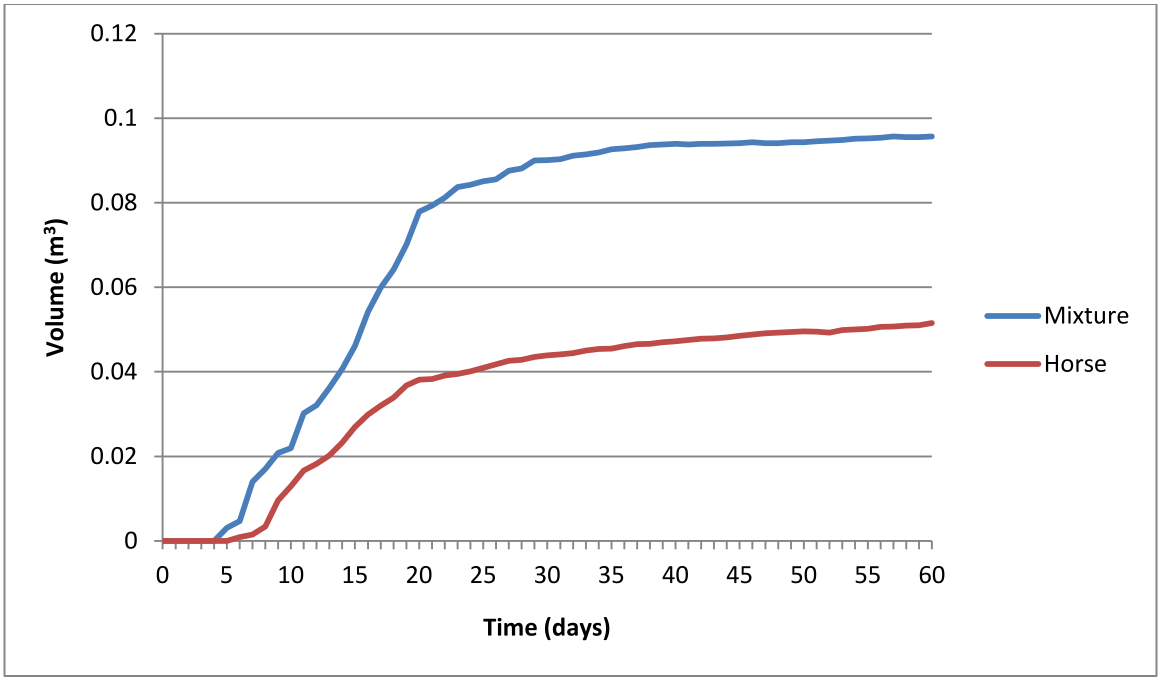


Figure 5-2: Volume and rate of biogas produced from the mixture and horse manure samples

The main aim for this test was to determine if the mixture, including human excrement, would produce as much gas at the same rate as the usual feedstocks. The intention being to determine if the varied waste products from a rural property such as vegetable peelings, human excreta, leftovers, sawdust, animal manure, and other such matter would combine to form a sufficient feedstock to operate a reliable digester. It is clearly illustrated that it is superior to straight horse manure and is an acceptable feedstock for the digester design.

5.2. TEMPERATURE SENSITIVITY RESULTS

During the course of this test, the intention was to drop the temperature of the slurry evenly one degree per day down to 15°C and record the gas production rate variance. The fact that it was done in the early summer time meant that it was impossible to evenly regulate the temperature below approximately 25°C. The average temperature of the water would remain above this mark and with the apparatus at hand it was not possible to temperature switch cold water above the required mark. The purpose of the test was to determine the response to standard temperatures so it was resolved by simply draining the water and allowing the container to revert to air temperature.

Temperature Sensitivity Results

DAY	TEMPERATURE(°C)	BALLOON (m)
0	35	0
1	35	0
2	35	0
3	35	0
4	35	0
5	35	0
6	35	0
7	35	0
8	35	0
9	35	0.261
10	35	0.329
11	35	0.360
12	35	0.398
13	35	0.435
14	35	0.455
15	35	0.465
16	35	0.501
17	35	0.491
18	35	0.499
19	35	0.493
20	35	0.498
21	34	0.497
22	33	0.491
23	32	0.493
24	31	0.482
25	30	0.479
26	29	0.490
27	28	0.503
28	27	0.465
29	26	0.451
30	25	0.448
31	Air temp	0.46
32	Air temp	0.452
33	Air temp	0.436
34	Air temp	0.393
35	Air temp	0.401
36	Air temp	0.359
37	Air temp	0.454
38	Air temp	0.436
39	Air temp	0.388
40	Air temp	0.439
41	25	0.442
42	26	0.451
43	27	0.483
44	28	0.503
45	29	0.495
46	30	0.507
47	31	0.517
48	32	0.501
49	33	0.506
50	34	0.523
51	35	0.537
52	35	0.553
53	35	0.545
54	35	0.551
55	35	0.533
56	35	0.500
57	35	0.498
58	35	0.505
59	35	0.499
60	35	0.501

Temperature Sensitivity Results

DAY	TEMPERATURE(°C)	VOLUME (m^3)
0	35	0
1	35	0
2	35	0
3	35	0
4	35	0
5	35	0
6	35	0
7	35	0
8	35	0
9	35	0.0003
10	35	0.0006
11	35	0.0008
12	35	0.0011
13	35	0.0014
14	35	0.0016
15	35	0.0017
16	35	0.0019
17	35	0.0020
18	35	0.0021
19	35	0.0020
20	35	0.0021
21	34	0.0021
22	33	0.0020
23	32	0.0020
24	31	0.0019
25	30	0.0019
26	29	0.0020
27	28	0.0021
28	27	0.0017
29	26	0.0016
30	25	0.0016
31	Air temp	0.0015
32	Air temp	0.0016
33	Air temp	0.0014
34	Air temp	0.0010
35	Air temp	0.0011
36	Air temp	0.0008
37	Air temp	0.0016
38	Air temp	0.0014
39	Air temp	0.0010
40	Air temp	0.0014
41	25	0.0015
42	26	0.0016
43	27	0.0019
44	28	0.0021
45	29	0.0020
46	30	0.0022
47	31	0.0023
48	32	0.0022
49	33	0.0022
50	34	0.0024
51	35	0.0026
52	35	0.0028
53	35	0.0027
54	35	0.0029
55	35	0.0026
56	35	0.0021
57	35	0.0021
58	35	0.0022
59	35	0.0021
60	35	0.0021

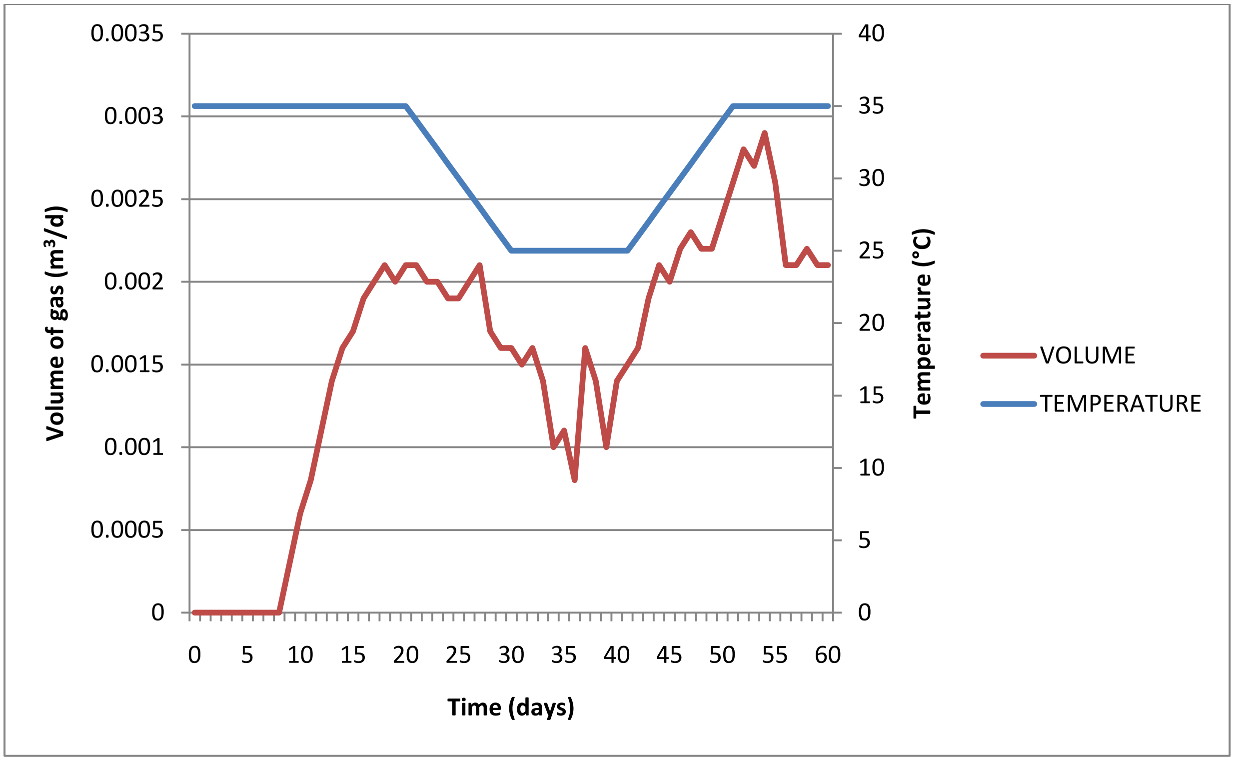


Figure 5-3: Gas production in response to temperature

It is obvious that the decrease in temperature had an effect in yield rate, but the increase in rate post temperature drop, beyond the initial stable rate indicates that the total gas production is not temperature dependant, only the rate is. Sudden temperature drops were not studied as they have little relevance on the concept at hand, a sudden temperature drop in a natural environment is very unlikely.

Previous study indicated that unheated biogas digesters were feasible in areas where the mean temperature is 15°C or higher. This temperature occurs most areas in Australia, for thermocline maps indicating these areas please see appendix D.

5.3. CHEMICAL SENSITIVITY TEST

The chemical sensitivity test results returned were negligible and not recorded here. The chemicals had no discernible impact, quite possibly due to their low concentration. This was the last test undertaken, and due to unforseen events and time constraints the results were inconclusive. It is mentioned in section 5.5 – Future Expectations, that the test will be repeated but with steadily increasing concentrations of chemical to determine the point where they inhibit the bacterial action.

5.4. SCALE MODEL RESULTS

In regards to the results from operation of the scale model, there is much yet to be done. The system needs to be modified to accept waste from a flush toilet so that it can be tested in that regard. The system has also yet to face the brunt of a hard winter, and the results on its resilience to low temperatures are pending those circumstances.

In order to discuss the progress of the scale model, the problems, potential problems, uncertainties, errors and solutions encountered during the course of the design process are listed below.

5.4.1 Challenges faced

Excrement collection -The nature of working with human faecal matter is unpleasant at the best of times. Collecting it was even more so. The author designed and built a toilet collection system, essentially a waterless toilet that gave the excrement matter some small time to dry out and easy access for collection.

Figure 5-13: Poop collection

Uniform testing -The levels of initial bacteria in the starting samples was obviously not uniform. This was clearly seen by the vegetable samples reluctance to begin anaerobic digestion without some bacterial stimulus. This may have introduced and error into the comparison of the rate of reaction over time.

Uniform mixture -During various stages of testing, reliable results were dependant on a uniform homogeneous mixture being used in the experiments. This may not have been the case, particularly with the mixture sample.

Figure 5-5: Poop measurement

Time delay	-In order to try and minimise the above error, on two occasions the mixture was made in advance of the testing and a sample from this mixture was added as the test progressed. This sample quite obviously did begin digesting and creating gas prior to being added to the test and may have compromised the results. This was overcome by premixing the combination without adding any water. The sample was not mixed perfectly due to its somewhat dry nature, but the gas production values were not impeded.
Gas scrubbers	-There was no way of testing the gas scrubbers. The balloons no longer perished, but the carbon dioxide may have still been present. As long as this was a constant error, then it was present in all testing and became irrelevant.
Liquid / Solid ratio	- A liquid to solid ratio of around 9:1 is a good target for digester operation. Though this target was aimed for, the author did not realise in time that the suggested ratio was not taking into account the water already in the feedstock. 9:1 is entirely possible using a toilet flush system, but when the fact that human excrement is already 80% water it makes the ratio significantly over watered. Will the system operate when connected to a flushing toilet system, or will the excessive water flow inhibit maintenance of a sufficient bacterial population. Also because of the high water content, heating the system become significantly more inefficient. Will the system operate without any heating has yet to be answered.
Balloon	-The balloon measurement system is not an overly accurate form of measurement. When the pressure and volume are low, the balloon is hard to evaluate because of its soft consistency. It is also not a sphere so there are inherent errors in the conversion from circumference to volume. There was also a very real possibility that a balloon would burst during a test, but because of the sequential cumulative nature of the tests undertaken, the balloon could be replaced and the test continued. The new volumes would simply have to be added to the previous, circumference values would no longer be relevant, but volumes would. The increasing pressure, as the balloons expanded, may have caused the gas to become more concentrated and hence make a non linear scale for the volume axis.
Wasting water	-The purpose of this report is to illustrate how to minimise waste. It seemed a little hypocritical to be wasting a large amount of water in the process of testing. It was decided to relocate the plant so the waste water could be utilised in irrigation.
Gas backup	-There is the potential if the toilet water traps and spark arrestors dry out for gas to return up the pipeline into the house. A system will be designed to prevent this from happening.

Location	-There is a weigh off between building the digester below or above the surface of the ground. The gains in temperature resilience may be outweighed by the increased difficulty in maintenance.
Mixing	-Is mixing necessary and does it decrease from reliability?
Accessible	-Should the interior of the digester be accessible?
Detention time	-How to ensure the waste is detained for the required period of time is also a core of the design. I was decided to make the system a modular design with multiple digestion tanks. When one is full it is closed to new input for the required amount of time while the second is used. The added benefit is that if a bigger system is required, more modules are simply installed.

5.5. FUTURE DEVELOPMENT

- Commercial potential for final design? Almost all the rural properties in Australia use septic systems of some sort to process their waste, there is an instant market;
- Potential to sell carbon credits;
- Research relevant standards - AS AS/NZS 1547:2000;
- Design spark arrester, filter and scrubbers into one combined unit;
- Develop calculations for digester volume per resident;
- Continue and endeavour change both my own and my world’s thinking;

6. CONCLUSIONS

"I only feel angry when I see waste. When I see people throwing away things we could use."
-Mother Teresa

At our moment in time renewable energy resources persist in being more expensive than their fossil fuelled counterparts. This is not a necessary evil. Cultural perceptions have the ability to be changed, but it will take a social and political will that is currently not being demonstrated.

Before any real change will be made there needs to be an admission that something is wrong. A number of affirmations need to be made.

- There IS a real problem that the generation of biogas can address;
- Biogas IS affordable;
- Biogas IS beneficial;
- Reducing waste IS a necessary goal;
- Creating a decentralised energy grid IS a positive goal;
- Being self sufficient IS a worthy target; and
- One person can make a difference.

This report should clearly illustrate how simple it is, even with what was very obviously very little expertise, to create a apparatus that is beneficial to both the users own immediate situation and the greater good. This is not a situation where the needs of the many outweigh the needs of the few. The needs all coincide.

A biogas generator was built, many challenges were faced, a difference was made, much fun was had, and a world was changed. The author hopes that you, the reader, have taken something from this work. The author certainly learned a lot and will continue to push on toward what must certainly be a better future for all. And remember:

If it's yellow, let it mellow. If it's brown, flush it down.

7. APPENDICIES

7.1. APPENDIX A – PROJECT SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

FOR: Mark COOPER

TOPIC: INVESTIGATION INTO DIFFERENT PRODUCTION LEVELS OF METHANE (BIOGAS) FROM A NUMBER OF DIFFERING YET READILY AVAILABLE FOODSTOCKS.

SUPERVISOR: Dr Talal Yusef

ENROLMENT: ENG4111 – S1, 2009
ENG4112 – S2, 2009

PROJECT AIM: This project aims to investigate the potential for small scale biogas production by anaerobic digestion. In order to increase self sufficiency and minimise waste produced by our society only the waste products that are created by a typical household will used.

PROGRAMME: **ISSUE A, 25th Mar 2009**

1. Research information related to biogas production and output levels from different digester designs.

2. Create an appropriate design for a small scale plant that is simple to maintain and build.

3. Build four (4) scale models of the chosen design.

4. Run four (4) concurrent scale model tests on animal waste, human waste, vegetable waste, and a mixed composition, using animal waste as the index point of reference. Compare the resulting yields.

AS TIME PERMITS

5. Research relevant health and safety standards related to septic treatment of household black and grey water.

6. Design and build a prototype septic system to Australian Standards incorporating biogas manufacture and sterile biomass output for potential commercial applications.

AGREED: ___________________________(student) __________________________(supervisor)

DATE: / / 2009 / / 2009

EXAMINER/CO-EXAMINER: ____

7.2. APPENDIX B - SAFTEY

Consequence \ Probability	1	2	3	4	5
A	1	2	4	7	11
B	3	5	8	12	16
C	6	9	13	17	20
D	10	14	18	21	23
E	15	19	22	24	25

Figure 7-114: Risk Matrix

A – Super mega (and potentially permanent) death.

B - Life threatening injury (user minus arm, leg, face or all of the above).

C - Serious injury or illness (temporary incapacitation).

D - Minor injury (potential for sympathy sex from partner – could be seen as a positive).

E - No injury (new underpants required).

* - Financial or environmental risks could be classified under each a to e depending on specifics

1 - Certainty.

2 - High probability.

3 - Possible.

4 - Improbable.

5 - Highly unlikely.

Physical Hazards and Risks

Hazard	Risk			Controls	Rank
	Probability	Consequence	Rank		
Travel accident	5	A	11	Follow Road rule Drive with safe vehicle	21
Injury during manufacture. Significant fabrication required. Welding, drilling and cutting risks are involved	2	D	14	Use correct PPE. Use correct procedures.	21
Slips, Trips, Falls	3	D	18	Avoid Slippery Areas, Rocks, Stable Footwear	20
Computer Injuries	3	D	18	Take regular breaks Stretch, Use Correct Posture	23
Exposure to pathogens. The exposure to pathogenic substances during the fieldwork is a high risk due to the nature of the work.	3	C	13	Wear correct PPE. Overalls, boots, rubber gloves, respiratory protection if spray likely. Minimise exposure through careful operations. Keep mind on the job. Ensure sanitary disinfecting procedures carried out regularly.	
Flammable gas. The methane based biogas that is the aim is extremely flammable and even explosive under the right conditions.	5	11	11	Carry out study in well ventilated area. Invest in a canary.	

Project Hazards

Hazard	Risk			Controls	Rank
	Probability	Consequence	Rank		
Poor time management	3	A	4	Undertake time management course Ask wife to help motivate	21
Poor/No Data Recorded	4	A	7	Try Again Backup Equipment	23
Unable to design solution to problem.	4	B	12	Try from another angle Ask supervisor	20
Poor Results	4	A	7	Regularly meet with supervisor to ensure work is on track Ability to re-test if necessary	23

Knowledge Hazards

Hazard	Risk			Control	Rank
	Probability	Consequence	Rank		
Poor interpretation of results obtained leading to incorrect results	3	A	4	Double Check Results Obtained Liaise with Supervisor Regularly	20
Poor Measurements due to Inexperience etc.	3	A	4	Constantly view the project as an Iterative Project Liaise with Supervisor Regularly	22

7.3. APPENDIX C – CONSEQUENTIAL EFFECTS

C.1 Development today should not undermine the development and environmental needs of future generations. The development of more sustainable practices such as alternative energies and biogas generation will aid the development, and facilitate the environmental needs, of the future generations. In furthering the level of information on alternative energy sources, this dissertation will help to reduce waste creation and increase public perception of this issue.

C.2 Environmental protection shall constitute an integral part of the process. There is the potential for contamination of the environment should there be a leak in the system somewhere. This could have all the negative effects of raw sewage being released into the environment, albeit on a much smaller scale. Every precaution to ensure no leaks and a design with the least number of liquid seals shall be the goal.

C.3 Engineering and surveying people should take into consideration the global environmental impacts of local actions and policies. The global impact of a society that is more aware of waste and willing to do something about it is a positive impact.

C.4 The precautionary approach should be taken – scientific uncertainty should not be used to postpone measures to prevent environmental degradation. Although much uncertainty shall abound during the course of this dissertation, everything that can possibly be done to create a better outcome for the immediate and global environment shall be done.

C.5 Environmental issues should be handled with the participation of all concerned citizens. There are only positive environmental outcomes perceivable. In the very worst case scenario there will be no environmental outcomes.

C.6 The community has a right of access to, and an understanding or, environmental information. Dissertation will be structured in such a way to be accessible, and easily understandable to the general community.

C.7 The polluter should bear the cost of pollution and so environmental costs should be internalized by adding them to the costs of production. This dissertation is aimed at reducing pollution.

C.8 The eradication of poverty, the reduction in differences in living standards, and the full participation of women, youth and indigenous people are essential to achieve sustainability. The goal of changing popular culture and thinking is one of the main goals of this project. To change popular culture and thinking in one area inherently changes thought process in all areas. When a person's eyes are open in one aspect, they inevitably analyse their commonly held perceptions to see if they bear up to the scrutiny also. This is a positive outcome for all of society, including women, youth, and indigenous populations.

C.9 People in developed countries bear a special responsibility to assist in the achievement of sustainability. The technology that is the focus of this study is already widely used in the developing nations. The focus then as such, is to foster a situation where it is more widely utilized worldwide.

C.10 Warfare is inherently destructive of sustainability, and, in contrast, peace, development and environmental protection are interdependent and indivisible. It is not the aim of this study to start a war. International understanding may be more closely grasped when there is a common sustainable goal.

7.4. APPENDIX D – THERMOCLINE MAPS

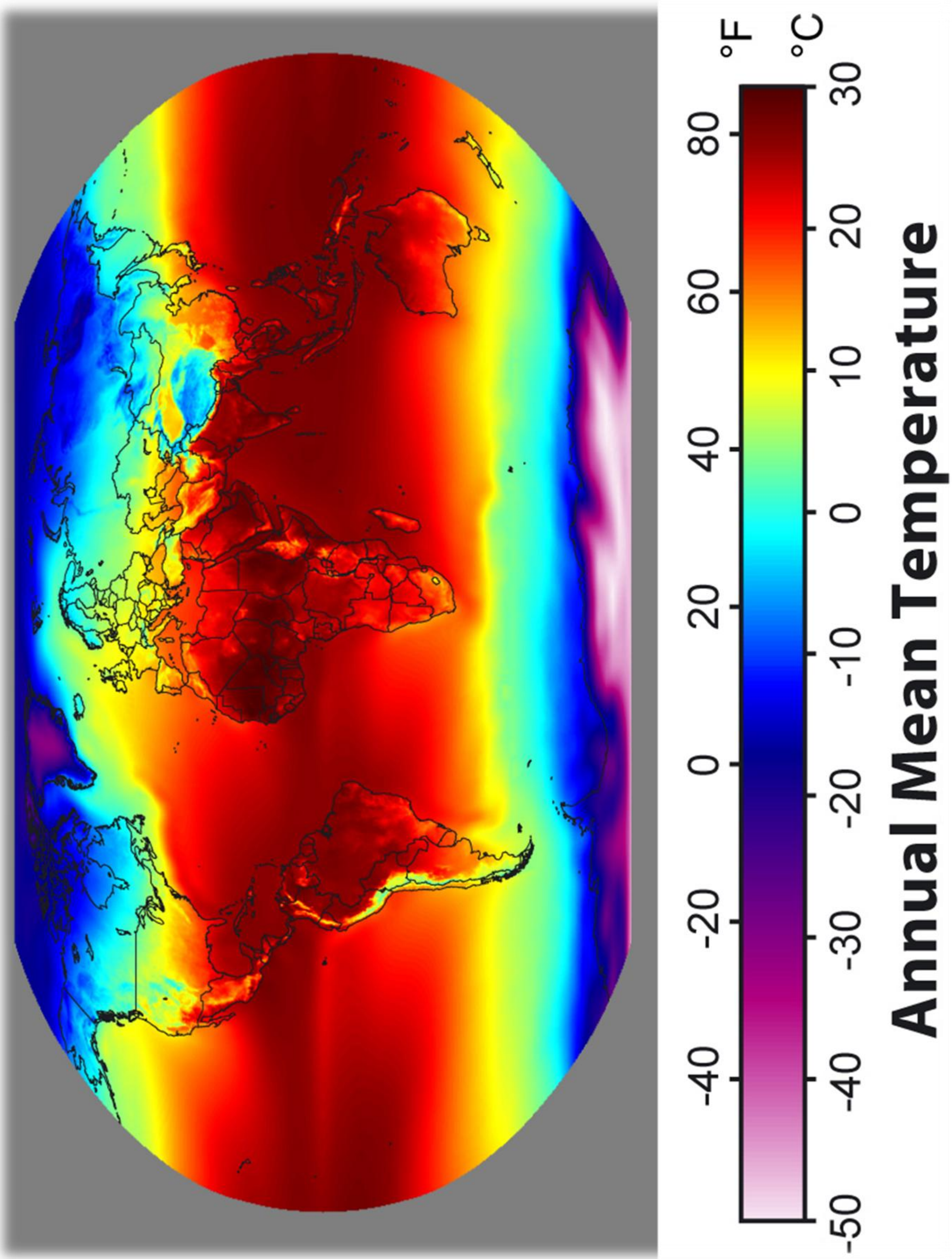


Figure 7-2: Thermocline map of world

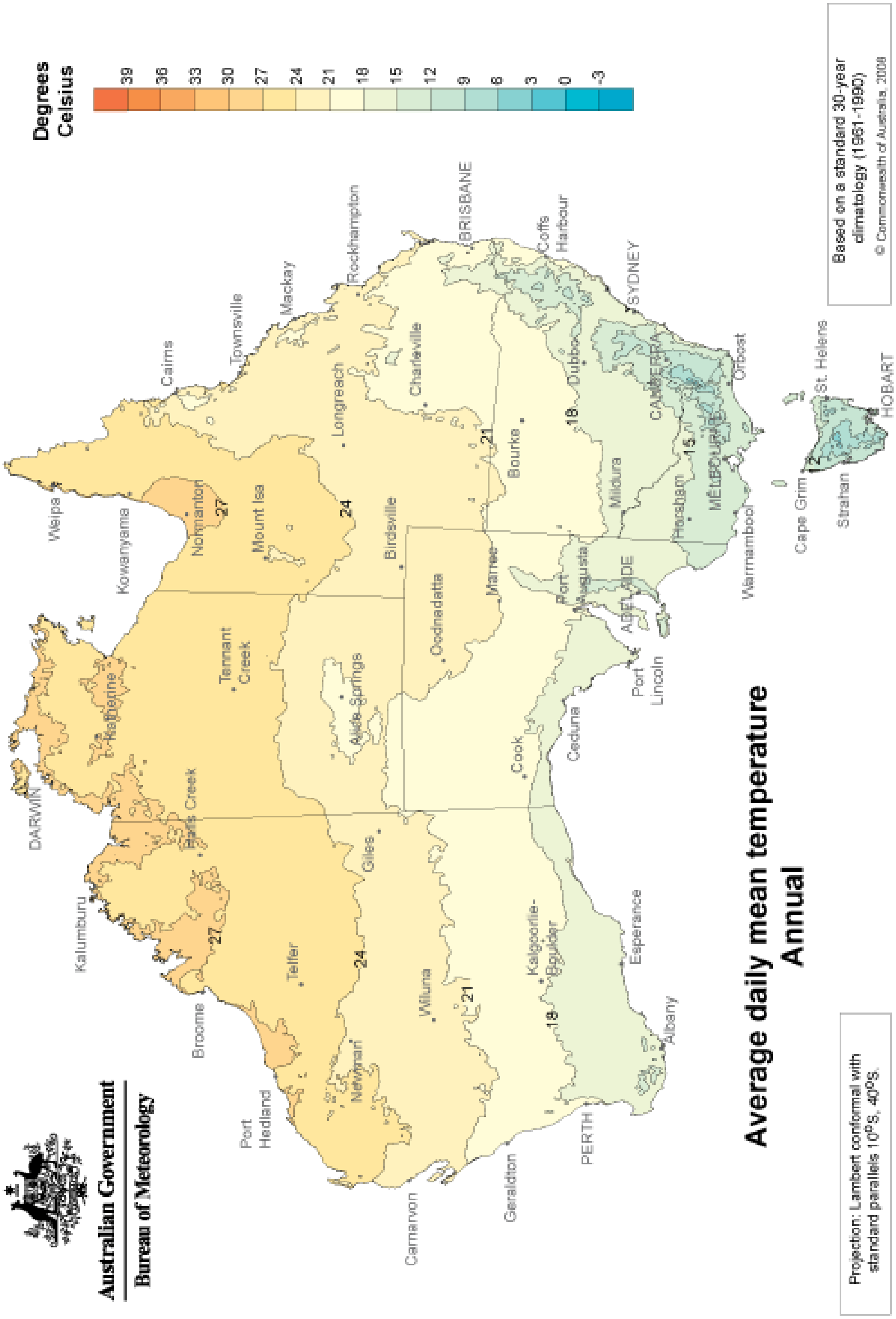


Figure 7-3: Average thermocline map of Australia

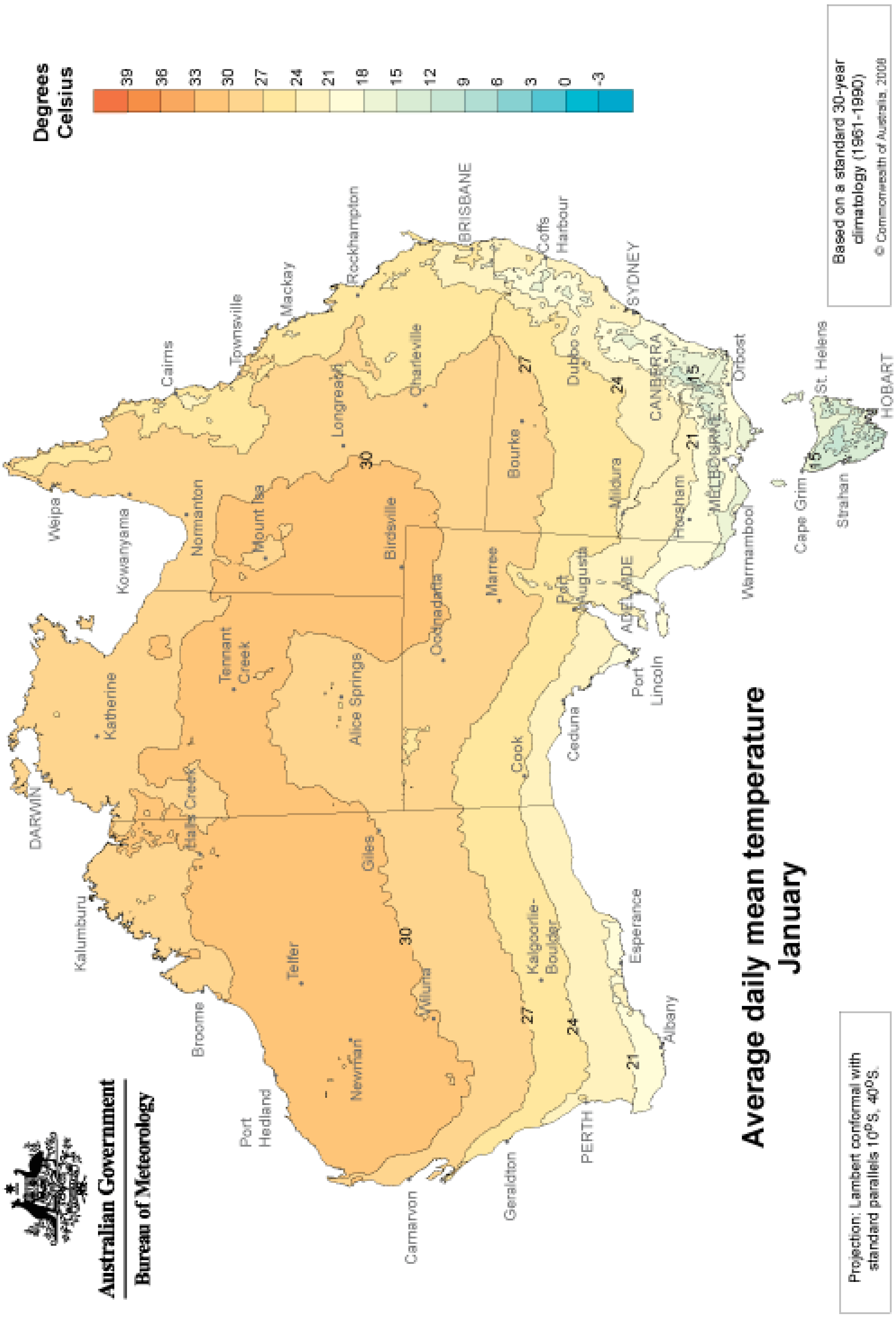


Figure 7-4: Summer thermocline map of Australia

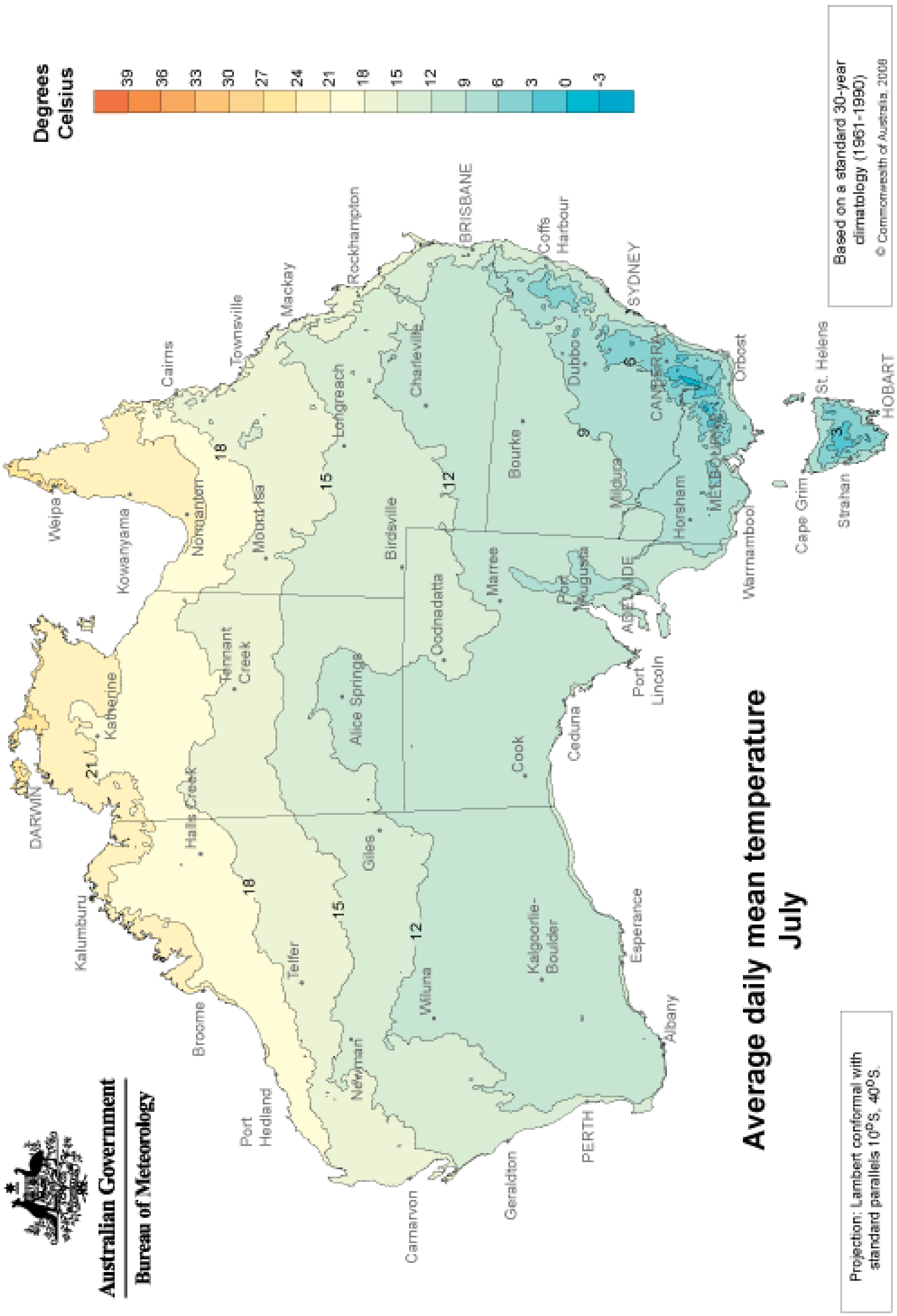


Figure 7-5: Winter thermocilne map of Australia

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