The Man Who Ate Himself

Why overpopulation and overuse of resources
will lead to humanity's decline

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Abstract

Around the world, human societies face a multitude of significant risks, including;

- global warming
- lack of clean drinking water
- famine
- habitat loss
- disease

While each of these risks and problems has a number of causes, overpopulation is consistent among them.

This paper attempts to show that there are too many human beings on this planet and that humanity is using up the world's resources at a significantly higher rate than they can be regenerated. These two effects combined, if unchecked, will ultimately lead to a population crash and possibly, our extinction.

Keywords: Carrying Capacity, Malthusian, Overpopulation, Population, Resources, Sustainability

"Instead of controlling the environment for the benefit of the population, maybe we should control the population to ensure the survival of our environment."

Sir David Attenborough
The Life of Mammals - 2004

"The future of our planet is in the balance. Sustainable development can be achieved, but only if irreversible degradation of the environment can be halted in time. The next 30 years may be crucial."

Sir Michael Atiyah (President Royal Society of London) and
Dr Frank Press (President U.S. National Academy of Sciences)
"Population Growth, Resource Consumption and a Sustainable World - 1992"[1]

". . . if you were designing an organism to look after life in our lonely cosmos, to monitor where it is going and keep a record of where it has been, you wouldn't choose human beings for the job."

Bill Bryson
A Short History of Nearly Everything - 2003

Introduction

Our species is facing a significant threat to our survival. While we are not the most abundant species on the planet, we have the greatest influence over it. We consider ourselves to be the most intelligent of the animals that call Earth home, but as this paper demonstrates even the most brilliant animal cannot outwit the laws of nature.

Less people means less use of carbon fuels, means more food and water available per head of population and means less use of available resources and greater opportunity for those resources to replenish themselves.

The paper begins with an analysis of theoretical and real population growth before moving on to examining the resources that we use, our dependence on them and their current state before discussing some possible solutions to the problem of overpopulation.

From a global perspective, I believe that we humans should set ourselves the goal of ensuring the long term, quality survival of our species.

From an actuarial perspective, our profession is uniquely positioned to examine the topic of overpopulation. Our occupation’s core strength is to examine and analyse data while taking a long term view, and integrated with this is an understanding of the demographic factors of mortality and birth. Consequently, I would like to think that at a minimum, this paper will provide a basis for further discussion by Institute members on the topic of overpopulation. At best I hope that the Institute and its members may consider this topic as being at least as important as climate change and to try to use our skills to influence those in power to make the fundamental changes that are required to avoid disaster.

Not Quite An Original

Robert Thomas Malthus

Before I begin, I would like to point out that this paper is anything but original.

In 1798 Robert Thomas Malthus, an economist by training, published what was to become his most well known work, 'An Essay on the Principle of Population'[2]. In this work he proposed a number of key ideas:

- that population increases geometrically, but the resources required for survival increase arithmetically
- actual population growth is kept in check by two broad methods
- 'Positive Checks' - disease and starvation which increase the death rate
- 'Preventative Checks' – such as delaying marriage, which lead to lower birth rates
- that in nature animals and plants produce more offspring than can survive
- any benefit from increasing the incomes of the poor is lost from an increase in birth rate

At the time, his views were somewhat revolutionary, and influenced naturalists such as Charles Darwin[3]. On the other hand some social reformers were opposed to his views as they contradicted their own beliefs on how to improve society[4].

Thwarted Again and Again

Given that the population of Britain was about seven million when Malthus wrote his essay and it is currently around sixty million, it would be easy to conclude that his reasoning was flawed. The following table shows the increase in population and food supply since Malthus first penned his essay.

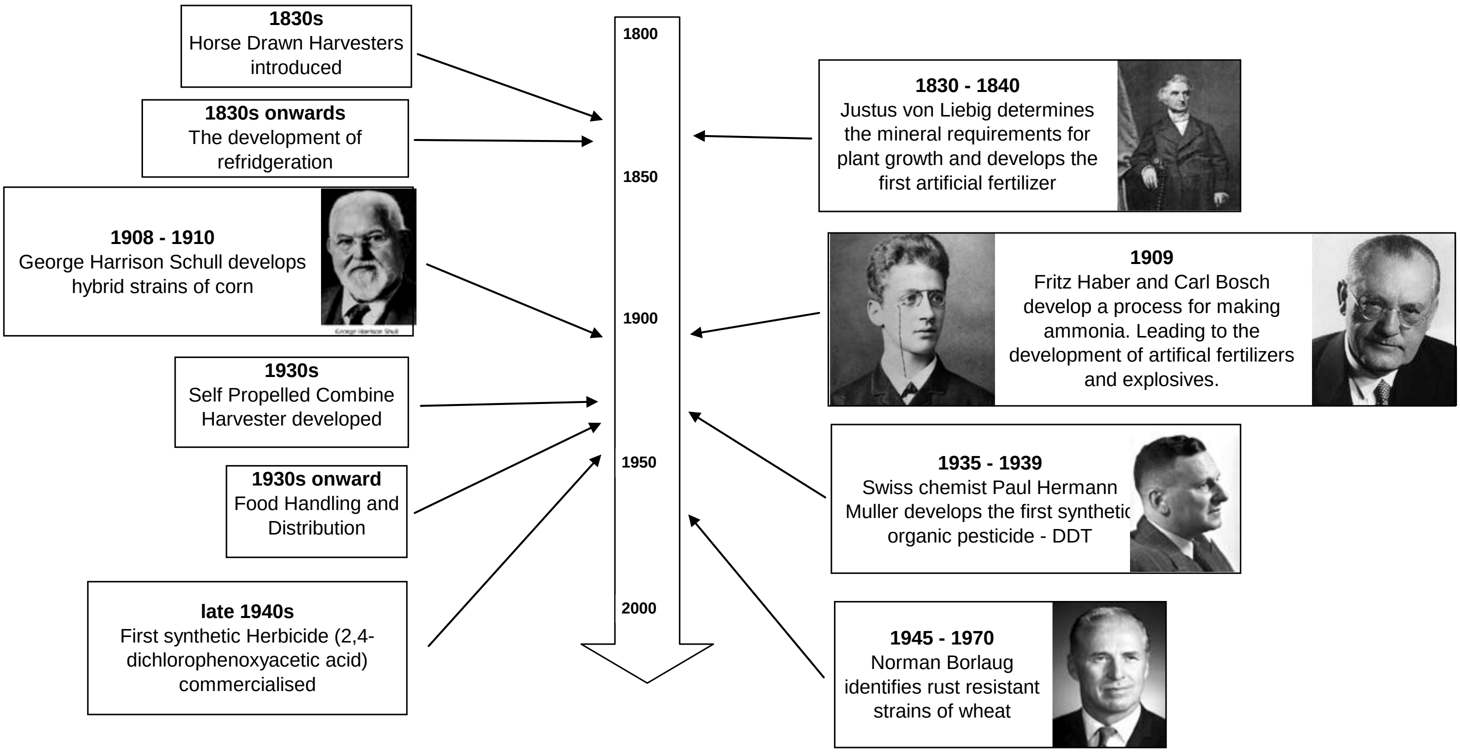
Figure 1 - Increases in population and food production [5] [6]

	Yearly Figures				**Ratios**	
	1700	**1961**	**1993**		**1993 / 1700**	**1993 / 1961**
Human Population (billions)	0.5	3	5.5		11.0	1.85
Cropland (Area Mha)	270	1,340	1,450		5.5	1.1
Average Production per capita (Kcals/d)		2,235	2,699			+20%
Protein per capita (g/d)		62	71			+15%
Malnourished (millions)		917 (35%)	839 (21%)			-14%
Comparable Food Prices		100	47			-53%
Cereal Yields		100	196			+96%

The table shows what Malthus correctly predicted, population increase since 1700 has exceeded the increase in cropland. Yet despite this, we have still managed to generate enough resources for our survival and, as the figures since 1961 show, our standard of living has also increased!

At various times during the past 200 years there have been periods where it seemed that the food supply would run out. Yet time and time again, scientists have successfully managed to come up with innovations which have increased our food supply. The following diagram lists a number of these discoveries that have helped boost our agricultural productivity and avoid a human catastrophe during this time.

Figure 2 – Agricultural Developments during the past 200 years



So given that the past 200 years clearly indicates that we are resourceful enough to come up with a solution, why should we expect the future to be any different? The key difference, as I see it, is that since 1900 increases in the production of key crops has been based in part on the use of other finite resources.

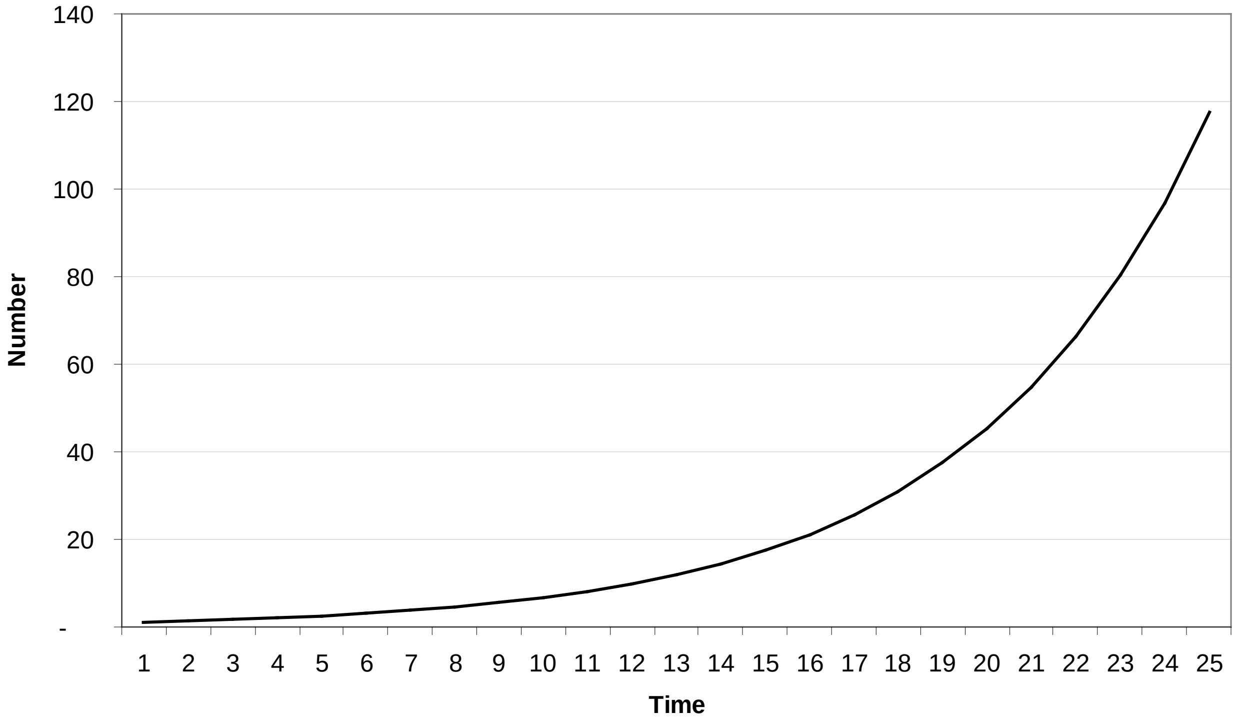
To illustrate this point, the work of Scholl and Borlaug in the development of crop selection would still work in the absence of other technologies. But the use of combine harvesters and the creation of ammonia for fertilizer rely on other finite resources and without alternative fuels being sourced to replace these, our current system will collapse.

Population Growth

Theoretical Population

Assuming that conditions are right and needs are met, organisms will have offspring. This is a fundamental step in the cycle which we call life. As mathematicians we can show the change in population size over time and the curve shown below is an example of one such population increase.

Figure 3 – General exponential growth curve



Mathematically a general curve of this type can be described in the following way*

$$P_t = P_0 \exp^{rt}$$

Where P_t is the population at time t and r, the parameter that determines the rate of increase, or decrease, is referred to as the Malthusian parameter. We use a curve of this form because the increase, or decrease in the size of the population is proportional to the number who existed at the previous time period.

This mathematics confirms what we intuitively know:

- if the replacement ratio (Malthusian parameter) is greater than 0, the population increases and,
- if the Malthusian parameter is less than 0, the population decreases.

Of course this is all pretty straightforward and well understood. The task now is to apply this mathematics.

Let us start with a small group of organisms, which I will call 'Blergs' (you can think of them as the biological equivalent of those 'widgets' that crop up everywhere in mathematics). Using the formula above, a starting number of 2 and a replacement ratio of 0.5, we can show that the size of the population follows this curve.

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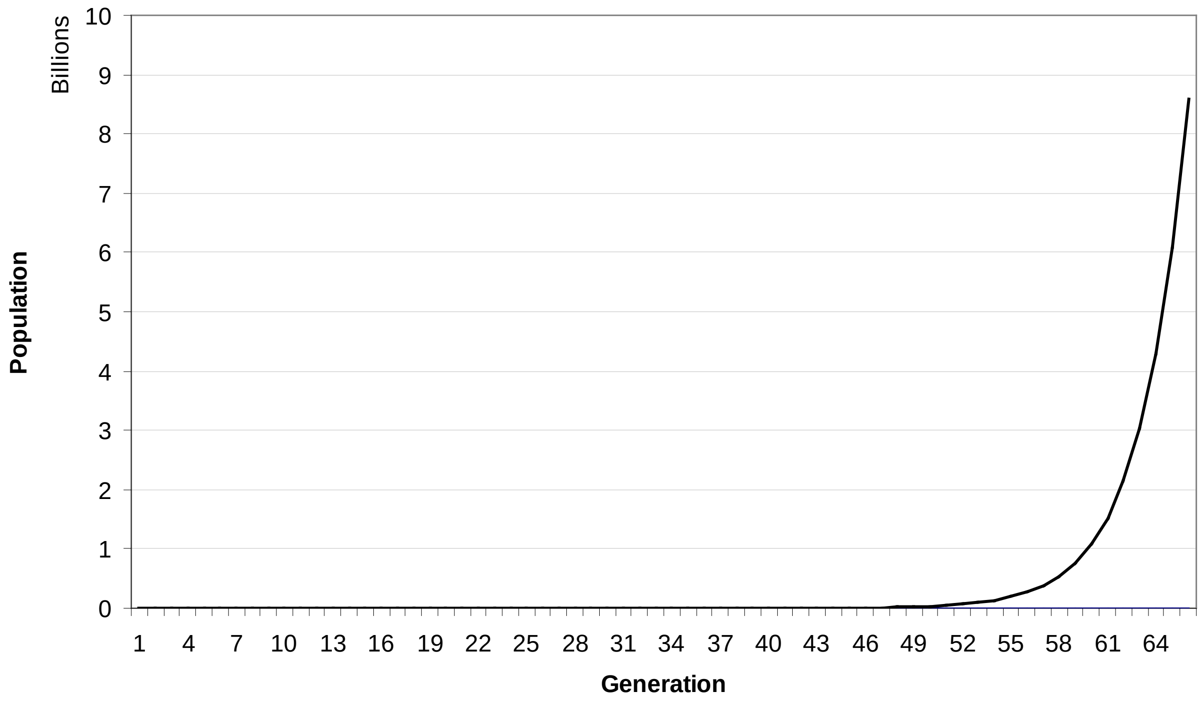
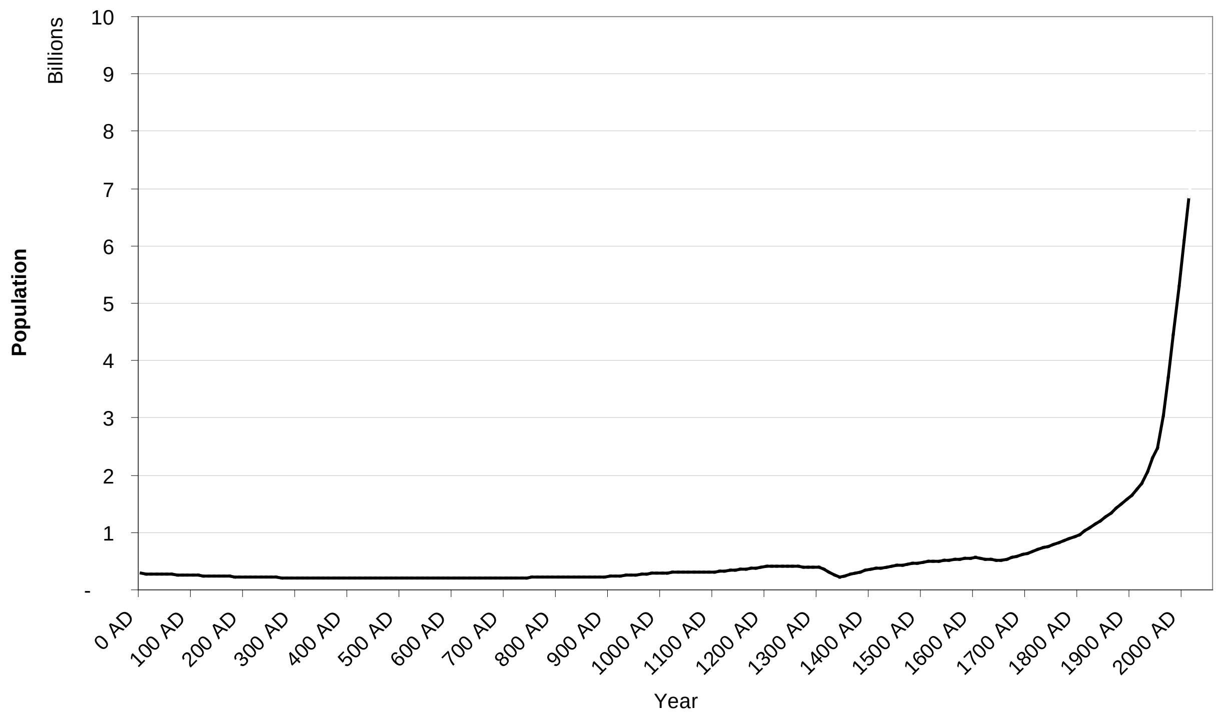
* This is the most simple population model and is used here to demonstrate the principle of exponential growth. For a more detailed explanation of exponential curves see appendix A.

Figure 4 – Exponential Growth Curve (P(0) = 2, r = 0.5)



The curve above can be compared with that of the historical human population, shown below.

Figure 5 – Historical World Population[7]



Human Population

The curves are remarkably similar.

Looking at the curve and data in detail shows that our population has grown steadily more or less constantly since at least 1AD. There have been two significant downward 'blips' one around 1350 and the other around 1650, both due to ‘plague'.

Over the past 200 years the population increase has been substantial. This is due to a number of factors, including;

- improved agricultural methods (some of which are described in diagram 2 above)
- taking beds off floors
- increases in general hygiene
- the introduction of sewerage systems
- the discovery and use of coal and then crude oil
- the industrial revolution which ultimately lead to less manual labour
- improvements in medical science, especially virology leading to cures for many bacterial and viral infections
- vast increases in our scientific knowledge
- improvements to diet

The drive of population it seems, is relentlessly upward, for despite, approximately 200 million[8] people being killed during the 20th century in wars and conflicts, the Spanish Flu epidemic of 1918-19 killing a further 20-40 million[9], China’s one child policy and countless other natural disasters, epidemics and famines, the size of the population has continued to increase.

Now so far, everything I have discussed is pretty well understood and if I was to stop this paper here I would be hard pressed to justify why anyone should read it. So let us return to the Blergs for one last time and see if they can teach us anything.

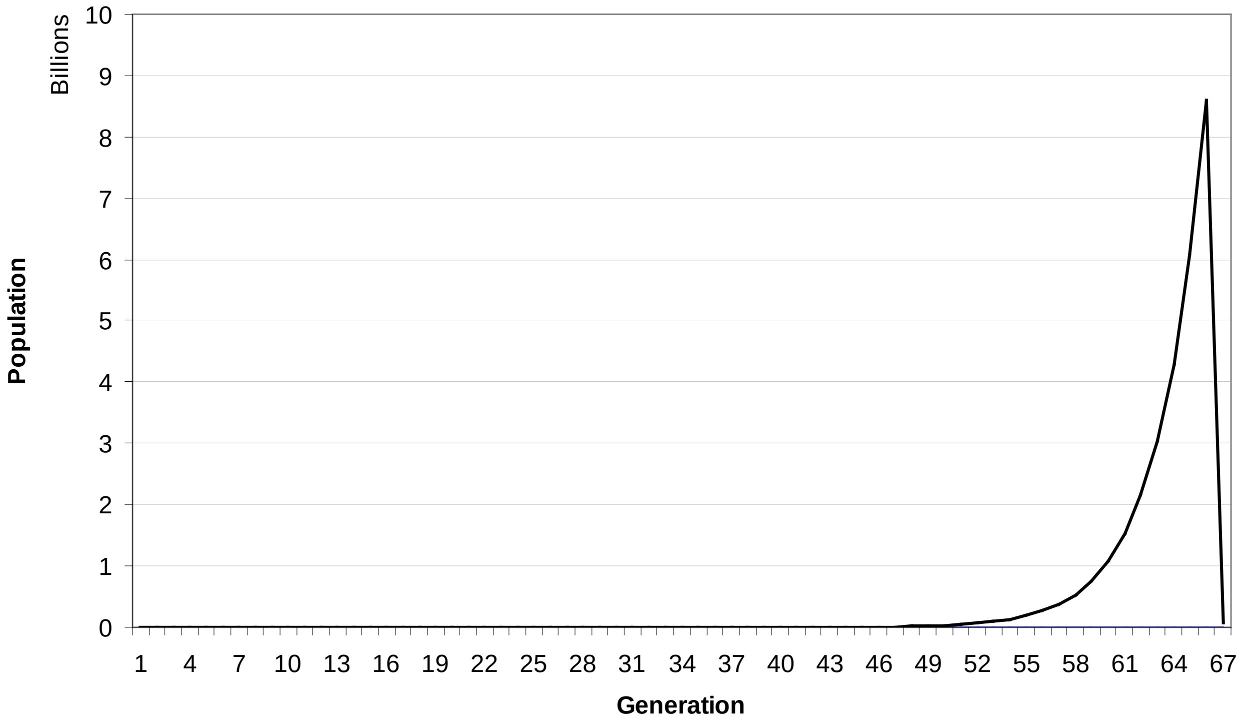
Onwards and Upwards?

When we last left them, the Blergs were doing well and the population had grown from a handful to eight and a half billion or thereabouts. Now I say going well, because, for the most part, the Blerg's economy, whatever that was, was growing, the cost of everything was well understood and the vast majority of Blerg were content.

But ultimately, the Blerg had a problem, they were running out of room, and with each successive generation the available room got less. Eventually, the last generation will enter a world where there are not enough resources for them to survive.

In the end the population curve looks like this;

Figure 6 – The demise of the 'Blergs'



Now you may be thinking, “Yes, but this is all very theoretical. I mean, we're smarter than bacteria – and, for that matter, Blergs – aren't we?”

Well, maybe, but history shows real life examples of this die off happening, and they are not within the confines of Petri dishes.

St Matthew Island Reindeer[10]

St Matthew Island is a small island (330 km2) situated in the Bering Sea. In August 1944, 29 reindeer (24 female and 5 male) were introduced to the island by the US Coast Guard, who had a short lived station on the island at that time.

With no predators on the island and an abundant supply of lichen to eat, the reindeer multiplied rapidly. A scientific study of the reindeer in 1957 showed that they were bigger and heavier than reindeer kept domestically. These studies also indicated that the rate of population growth was close to the theoretical maximum possible for this species with the population numbering 1,350.

In 1963 scientists returned once again to the island and found some significant changes to the population. While the number of animals had increased to 6000, the animals were smaller than they had been previously and the fawns had suffered an increased mortality rate. There had also been a significant reduction in the vegetation available for the reindeer to graze on.

In May 1964 an aerial reconnaissance of the island showed deeper than normal snow and no reindeer were spotted (this was in part due to the altitude and speed of the plane). However the die off of the herd was confirmed in August 1965 when Coast Guard personnel landed on the island and could only find 42 animals, all adults.

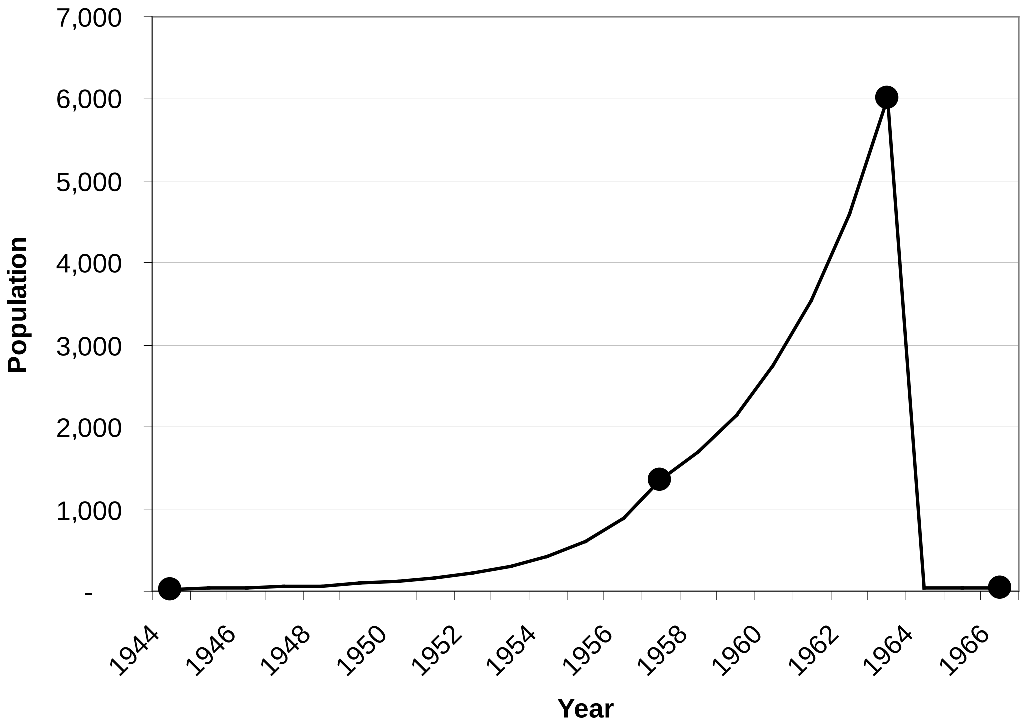
When scientists arrived in 1965 they confirmed that only 42 of the original herd had survived. Investigations carried out by the scientists indicated that;

- during the late winter of 1964 almost all of the population had died off
- only one juvenile male had survived this die off period which meant no pregnancies had occurred since the die off
- the lichen on the island had been transformed from being 8-12cm deep to 1cm deep and was badly

broken up meaning that winter forage was badly depleted
- summer forage was still abundant (which is consistent with other studies in Alaska which show that it rarely suffers from over use)

Based on the statistics from this analysis the following graph of the reindeer population can be drawn.

Figure 7 – Hypothetical reindeer population curve (actual counts marked with points)



In short the scientists concluded that the die off was due to:
- overgrazing of lichen
- excessive numbers of reindeer
- the poor health of the reindeer in 1963
- the deeper than normal snow in 1964

This example demonstrates quite clearly a rapid increase in population followed by a significant die off. Importantly this scenario has been observed in other introduced animals. In the interests of balanced reporting I should also point out that this scenario does not always eventuate and some introduced species have managed to regulate their population to maintain a stable size.

While it is instructive to see an example of growth and die off in a large mammal a possibly better example would be one involving humans and thankfully, there is one such example.

Rapanui (Easter Island)[11]

On Easter Sunday, 1722 Dutch explorer, Jacob Roggeveen happened across an inhabited island in the Pacific Ocean. The island was otherwise unknown by the rest of the world and being somewhat unimaginative, he named the place 'Easter Island'.

Most well known for its huge carved stone statues (Moai), when first discovered the island was home to an estimated population of 2,000 and it was described by Roggeveen and subsequent visitors (including James Cook) as a more or less barren and desolate place for despite its subtropical position and rich volcanic soil there was not a single tree over 2 metres tall on the entire island.

While Jacob Roggeveen may have been unimaginative with his names, he was smart enough to spot an apparent paradox about the island. How do you move statues weighing 80 tons without timber, rope or machinery? Over the years, archaeologists and palaeontologists have managed through excavations and exhaustive analysis of pollen grains, to piece together a plausible theory of what happened on the island.

From radio carbon dating and linguistic work, it seems that the first inhabitants arrived on Rapanui at around 400 AD, with the population peaking at about 7,000. Environmentally, from at least 30,000 BC, Rapanui was covered in sub tropical forest. This forest included palms 80 feet high and six feet wide; and shrubs that could be used for making rope. As for diet, excavations showed that the islanders, at least initially, built boats large enough to fish and capture porpoise to eat and dined on seabirds, land birds, rats and seals. In short, the descriptions show the island to be a bit of a paradise.

By 800 AD however the forests had already started to be burnt down, and by 1400 the palm tree mentioned earlier had disappeared (for good). And by the end of that century so to was the rest of the forest, as trees were cut down to make boats, for firewood and for moving statues. With the forest gone, so too were the land birds. Without timber to make boats, fish catches were reduced, as were other sources of meat. Cannibalism followed.

So, in the space of 1000 years, humans had managed to turn an otherwise pristine paradise into a barren land devoid of many of the things required for a comfortable existence.

Where Are We Headed?

The past therefore, shows us that, as a species, we appear to be no smarter than the bacteria in a Petri dish, who multiply to their ultimate demise. History also shows us that we must look after the resources that we use if we are to avoid the problems that occurred on Rapanui.

Interestingly, farmers are well aware of the need to take care of their local resources and limit the number of animals that they graze on land based on what they consider to be the ‘carrying capacity’ of the farm or pasture. Yet oddly enough this same concept never seems to be applied to ourselves. Another thing to note, is the extent of the population dilemma. International travel and trade now mean that it is no longer possible for countries to isolate themselves and be truly independent from the problems of other nations. This means that no single country can act singularly and hope to reduce this problem. In other words, the scope of this problem is truly global.

Resource Limits

Most organisms, in order to survive, require gas to breathe (O_2 or CO_2), water to drink, and food for nutrients. In addition, because we humans are a little more evolved than other species and feel a need to wander around a lot, we also require shelter and transport. Crucially, all of the things we need are supplied by the planet. All of the physical items around you as you read this - the clothes you are wearing, the seat you are sitting on, the screen or paper you are reading this document on - are all supplied by either farming or mining. There are <u>no</u> other sources.

Some of these resources can be classified as non-renewable (crude oil) while others can be thought of as renewable (such as forests and fish). Water, since it is neither created nor destroyed, is referred to as replenishable. These classifications suggest that different solutions are required to manage each of the resources effectively.

In order, to convince you that there is a problem, I'm going to run through some of the more crucial items that the planet supplies us and show their current and projected status.

Crude Oil

Of all the substances that the earth provides, this is currently the most valuable. It is the reason for our astounding (in historical terms) standard of living. Crude oil supplies us with plastics, pharmaceuticals, insecticides, cosmetics, clothing, fertilizers, etc (the list could continue for several pages). It supplies almost all of our transport needs and it is the reason for cheap manufactured goods. We use it to heat our homes and for cooking our food. It starts wars and fuels wars. Nothing, in our current way of living, is untouched by it.

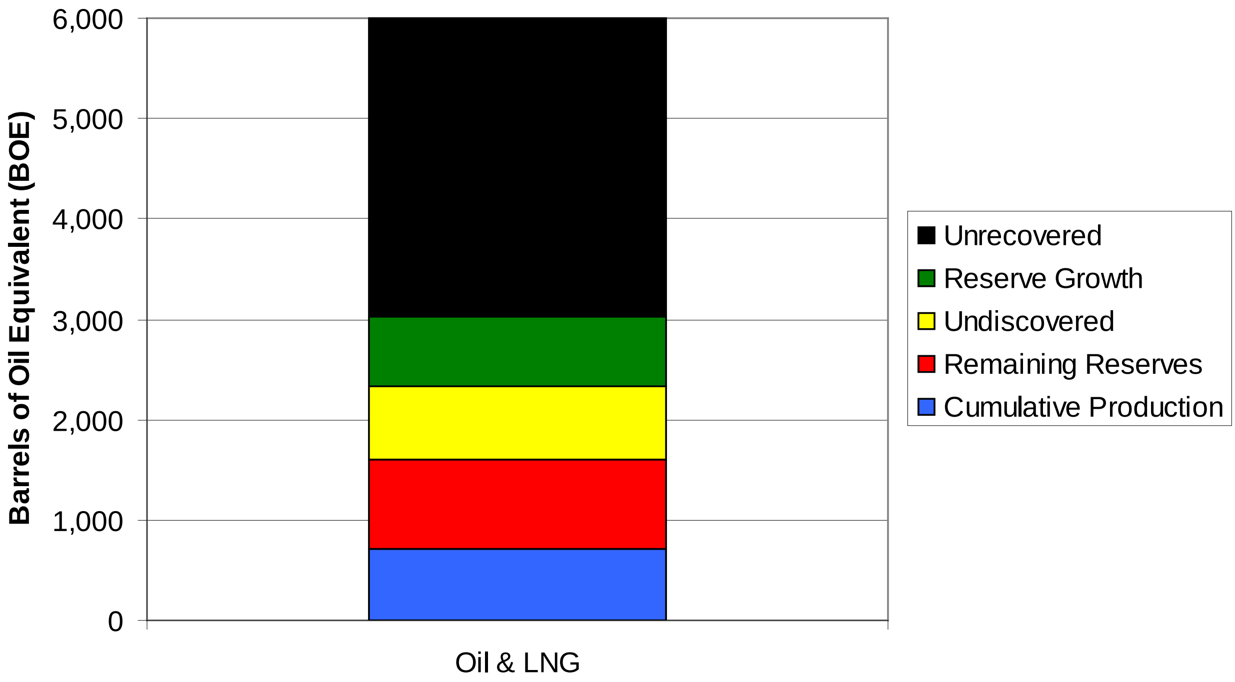
One consequence of petroleum being so common and freely available is that its chemistry and importance are underappreciated. To demonstrate consider the following[12];

- 1 barrel of oil contains the same energy as 12 men working for an entire year
- every calorie you eat requires 10 calories of hydrocarbons to grow it and deliver it to you

Given its importance to us, it is sensible to ask, how much do we use and how much is left?

The US Energy Information Administration (EIA)[13] appears to be the de facto central source for statistics and information on energy production and consumption (including crude oil and natural gas). In 2000 it produced a report based on data from a 5 year investigation by the US Geological Survey[14]. This study showed the following 'best estimate' of the breakdown of petroleum on Earth.

Figure 8 – Hypothetical 6,000 Billion Barrel, Original Resource Base



Based on these figures, over the past 100 years or thereabouts, we have managed to extract and use 710 billion barrels of oil and we have a central estimate that the remaining amount, likely to be recovered, is 2,300 billion barrels. This can be compared to our current rate of use of 84 million barrels pre day (mbpd).

Ultimately however, it is the amount produced and consumed that is important, for when production peaks, more than half the oil available has been extracted and it is running out. To this end the EIA came up with a range of scenarios as to when worldwide production of oil would peak. Their mean result, assuming 3,003 billion barrels to be recovered and demand growth of 2% pa, worked out at 2037 with a production rate of 146 mbpd.

There are many others however, that believe peak production will occur much earlier than 2037. Indeed, more recent reports from the EIA seem to bring into question their previous estimates from 10 years ago.

Some statistics which contradict the EIA study include:

- China's demand for petroleum has increased from 1.7 mbpd in 1980 to around 8.2 mbpd in 2009. This is a growth rate of 5.5% pa, which is significantly higher than the initial demand prediction of 2% pa sighted in the earlier report.
- In each of the past 4 years the EIA has lowered its predictions about the level of worldwide production to the point where for the next 10 years they predict that production will increase from only 85.5 mbpd now to 92.1 mbpd in 2020[15]. This is significantly lower than their initial estimate of 146 mbpd in 2037.
- The EIA best estimate resource of 3,003 billion barrels is considerably larger than all other previous estimates of total crude oil resources. They described their own estimates as more technically sound than past estimates.
- Despite the recovery of oil at substantial rates, the reserves published by major OPEC producers continue to grow. Consequently there is some doubt as to the validity of these reserve amounts[16].
- Since 2004 the daily production of crude oil (excluding natural gas) has averaged between 72 mbpd and 74 mbpd. This does not bode well for the increases required to supply developing nations with the oil they desire.

Determining the exact time when crude oil will run out is not possible. But based on recent production rates it is likely to be earlier than the 2037 prediction made by the EIA.

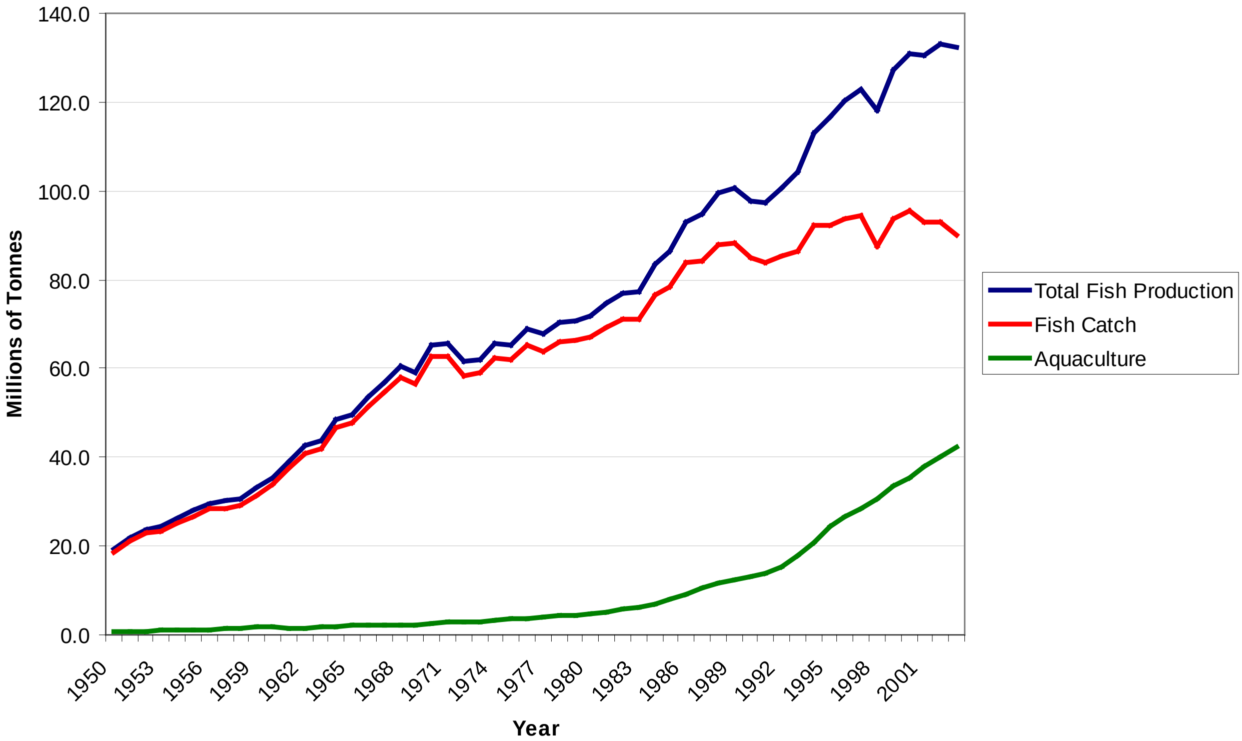
Fish Stocks and Aquaculture

Based on statistics from the Food and Agriculture Organization of the United Nations (FAO), each year more than 140 million tonnes of fish are caught around the world. Of this catch 110 million tonnes are used for human consumption[*]. This works out at roughly 16.5 kg per person per year. Clearly the oceans are a significant resource.

Over the past 50 years technology has lead to ever increasing catches of fish from the ocean. The following graph, based on FAO data, shows this increase in the worldwide catch.

Figure 9 - Historical Worldwide Fish Catch 1950 - 2003[17]

* Not all fish which are caught are for consumption. Up to 30% is for non-food uses.

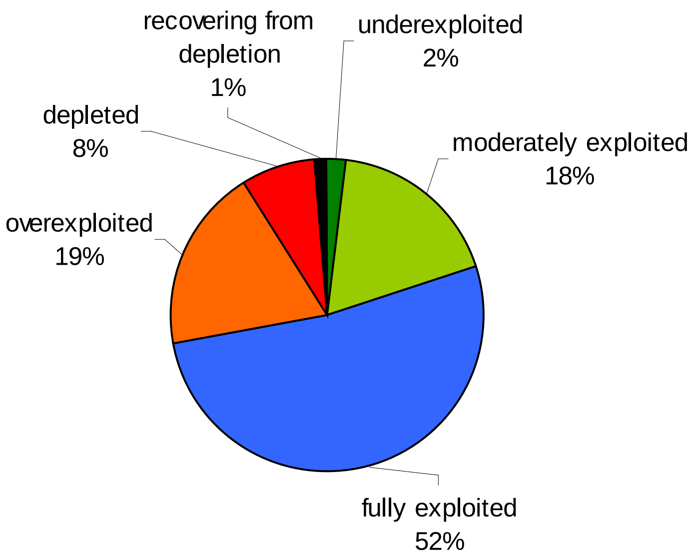


Of course provided the resource is large enough to replenish itself, the size of the catch doesn't matter. Unfortunately the most recent data from the FAO provides a less than positive outlook. It classifies fish stocks according to the following categories:

- underexploited
- moderately exploited
- fully exploited
- overexploited
- depleted
- recovering from depletion

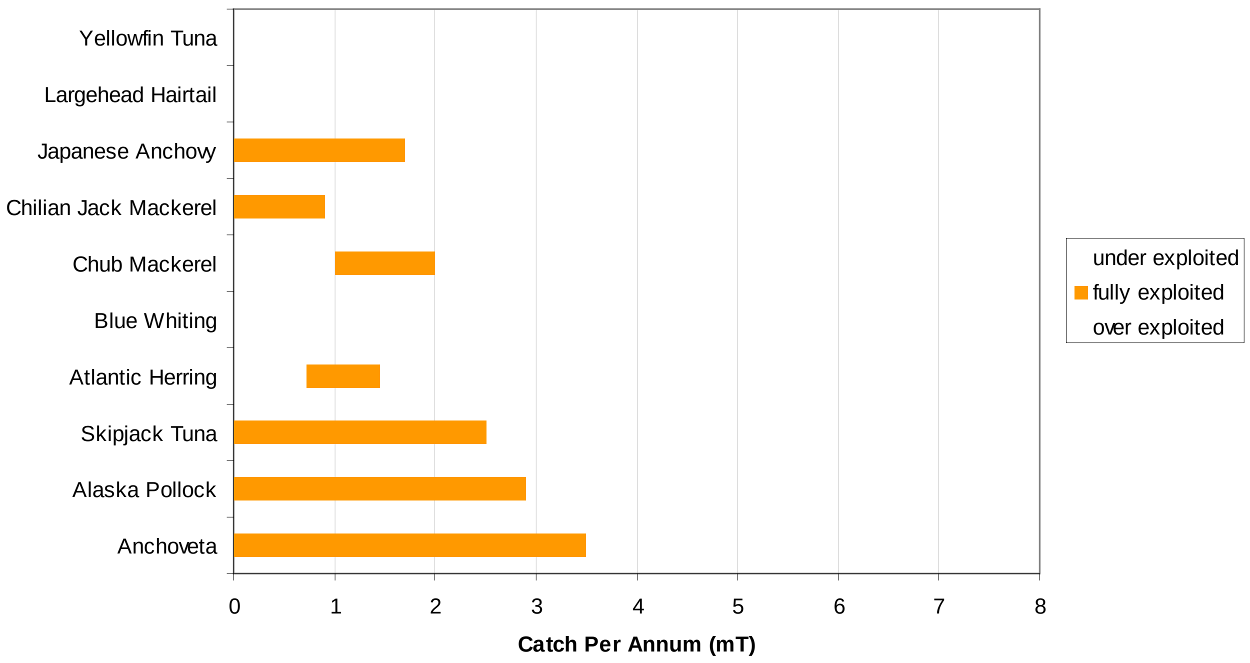
The following graph shows that over 75% of fish stocks are fully or over exploited.

Figure 10 – Breakdown of fish stocks according to FAO classification[18]



Furthermore of the top 10 species of fish which are caught most are fully or overexploited. These species account for 30% of the total worldwide catch.

Figure 11 – Top ten species by catch with indication of exploitation18



Unsurprisingly, data tables from 1974 to the present show that the proportions of fish categorised as overexploited or depleted has risen and those classified as underexploited have fallen.

From all this it is clear that as the world's human population continues to increase, it will not be possible for fish stocks to recover but rather they will continue to become depleted.

Forests

Just like the inhabitants of Rapanui (Easter Island), we rely heavily on forests. Apart from using the timber for building and burning, forests reduce water run off and consequently soil erosion. Additionally plants which are found in forests are used in the development of medicines and chemistry. Finally, forests produce oxygen from carbon dioxide.

Thankfully the news on the world's forests is more positive than it is for fish stocks and crude oil. Of course positive is a relative term, in that the rate of deforestation around the globe has decreased. Unfortunately while the rate of deforestation has decreased forest continues to be lost. The following two charts - based on data from 'The United Nations Global Forest Resources Assessment 2010'[19] – show that we have less forest than we did 20 years ago and indicates the areas where the reduction has been greatest.

Figure 12 – Forest Coverage by Continent

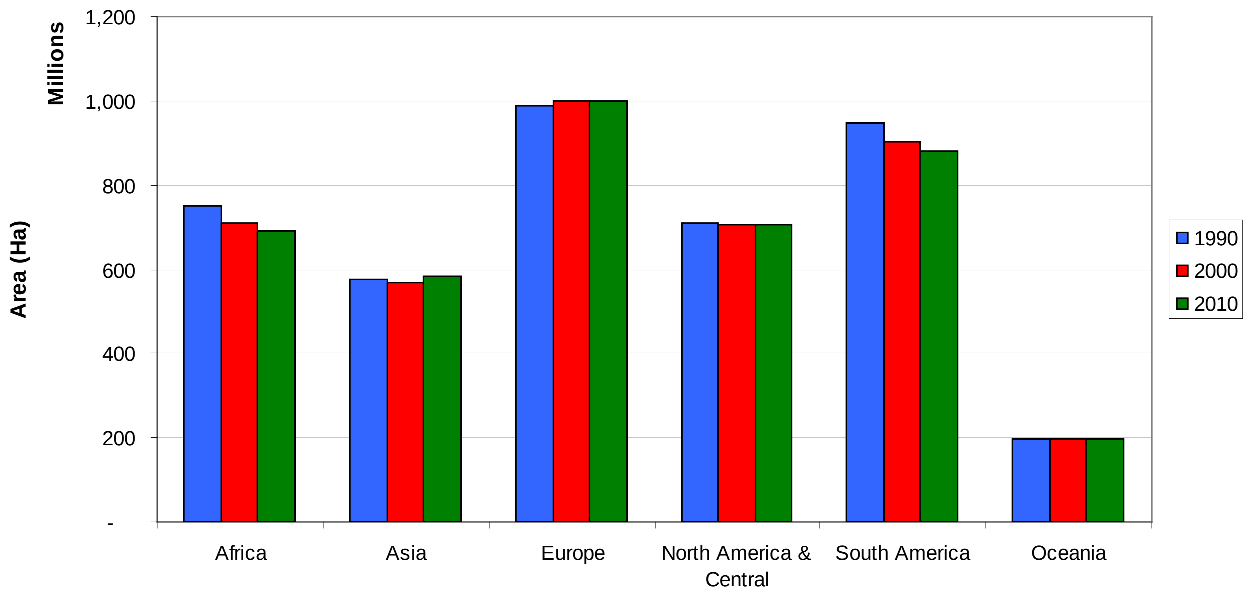
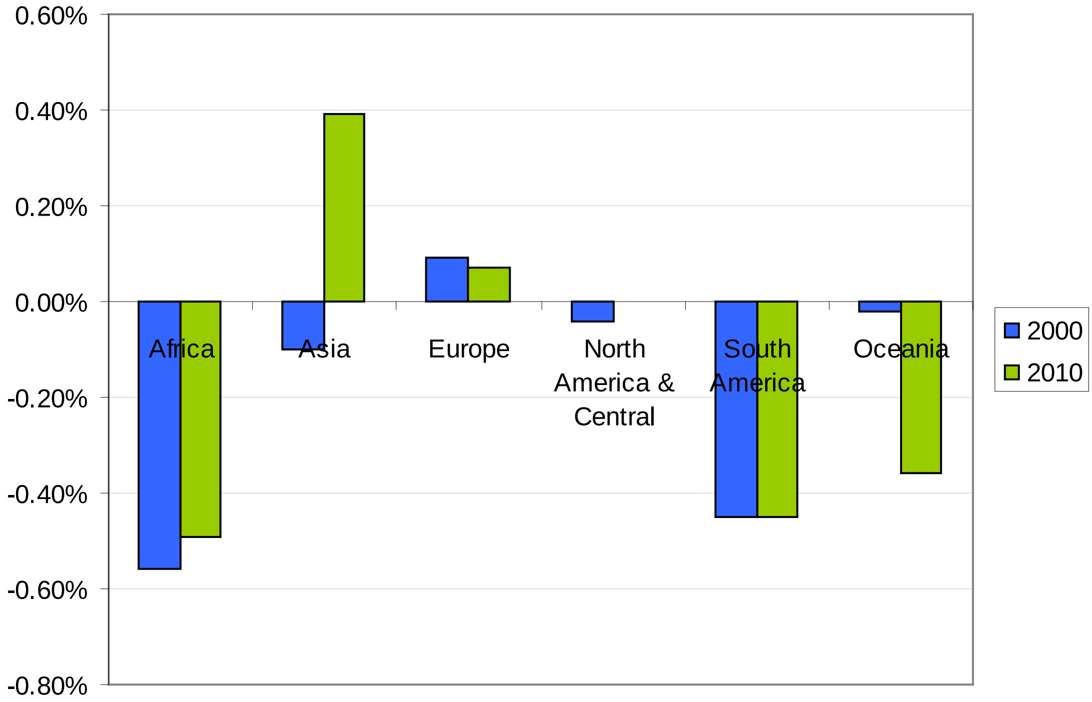
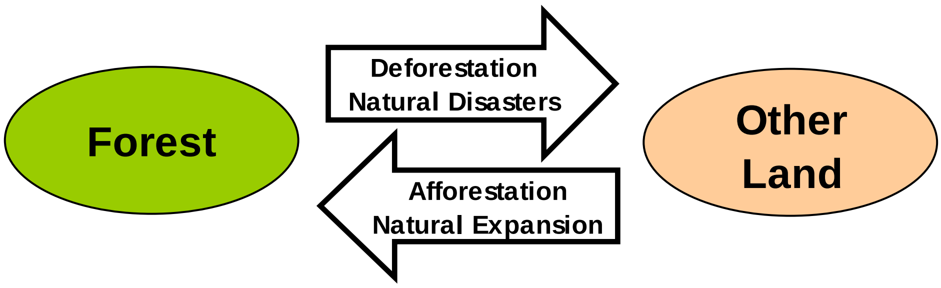


Figure 13 – Proportional Change in forest coverage by continent



Interestingly both charts show that forest coverage in Asia has increased in the last 10 years. This curious fact can be explained by the diagram below.

Figure 14 – Changes in Forest Area



During the past 20 years the Chinese Government has managed to increase China's forests by 49.7mha by planting schemes, and this amount has more than covered the loss of forests in other Asian countries such as Indonesia.

While this is good news, the biggest negative with respect to deforestation remains the loss of primary forests. The FAO divides forests into three categories:

Forest Type	Description	Recent Change
Primary	Native forest with few signs of human disturbance	Represent 1/3 of the world's forests. Decreasing at a rate of 0.4% per year over the past 10 years
Naturally Regenerated	Regenerated forest created without the assistance of humans	Decreasing
Planted	Created through human planting schemes	Increased by 5m ha per year over the past 10 years across all continents

Primary forests have decreased by 40mha over the past ten years and continue to be logged at alarming rates. The following table confirms this, with the biggest losses to forests around the world being in countries which are cutting down their primary forests. Not only does this reduce the number of trees but also reduces biodiversity (which may never be able to be recreated in a planted forest).

Figure 15 – Countries with largest net loss of forest 1990 - 2010

Annual Change (1990 - 2000)

Country	1,000 ha/year	%
Brazil	- 2,890	-0.51
Indonesia	- 1,914	-1.75
Sudan	- 589	-0.8
Myanmar	- 435	-1.17
Nigeria	- 410	-2.68
Tanzania	- 403	-1.02
Mexico	- 354	-0.52
Zimbabwe	- 327	-1.58
The Congo	- 311	-0.2
Argentina	- 293	-0.88

Annual Change (2000 - 2010)

Country	1,000 ha/year	%
Brazil	- 2,642	-0.49
Australia	- 562	-0.37
Indonesia	- 498	-0.51
Nigeria	- 410	-3.67
Tanzania	- 403	-1.13
Zimbabwe	- 327	-1.88
The Congo	- 311	-0.2
Myanmar	- 310	-0.93
Bolivia	- 290	-0.49
Venezuela	- 288	-0.6

Not all deforestation is man made however. Australia is second only to Brazil in terms of percentage lost of natural forest, however a majority of this is due to drought and fire, rather than cutting trees down for timber.

Water Resources

Water is another resource which is essential for our survival but freshwater resources are also being stretched to their limits. This can be demonstrated by the following details in the WWF Living Planet Report 2010[20].

- It was estimated in 1995 that 1.8bn people lived in areas which experienced severe water stress.
- "The use of freshwater ecosystem services . . . is now well beyond levels that can be sustained even at current demands."

In addition to the water which comes out of the tap, you also have to consider 'virtual water'. To demonstrate consider a cup of black coffee that you might purchase at a cafe. The cup itself contains about 250ml of water, but what is not immediately obvious is that you have to account for the water that is;

- used by the farmer to grow and harvest the coffee
- used by the manufacturer in processing and transporting the beans
- used by the retailer in preparing it for sale
- used in the making of the disposable cup

If you take all of this water into consideration suddenly your single cup (250ml) of black coffee grows to 140 litres of water - or if you prefer a latte with sugar, 200 litres! [20]

Resource Conclusion

It is absolutely clear that we are using up our planet's resources faster than they are being replaced. By current estimates the planet that sustains us is able to supply total resources of 11.9 billion global hectares (gHa) of biocapacity each year. But in 2007, 6.6 billion humans used 18 billion gHa, that's 50% more resources than can be replenished each year. What's more, the United Nations estimates that the world's population is to grow to over nine billion by 2050.

What then, are we to do?

How will it be possible to increase the population by a further two and a half billion people - and for all of them to be supplied with enough water, food and shelter over their lifetimes - when we are already exceeding the planet's ability to adequately support the current population?

Can we avoid killing ourselves by over indulgence?

Solutions to this dilemma exist, but they are neither straightforward nor simple.

Solutions to Our Dilemma(?)

To avoid a looming catastrophe, we have to solve some very challenging problems, including;

- How to feed an estimated three billion extra people without being able to increase the amount of land on which we grow crops
- How to replace crude oil and everything that it provides
- How to supply everyone with enough freshwater for washing and drinking and for growing the extra crops that would be needed

These are challenges which are unprecedented in our history. In the past we have used other finite resources on which to base our solutions, but now, these are also running out.

In the final section of this paper, I will discuss a number of possible solutions to our dilemma, focussing on the following four areas:

1. Changing our attitude
2. Finding a replacement for crude oil and gas
3. Reducing our population
4. Reducing our resource use

Changing Our Attitude

The first and most crucial step, if we are to avoid consuming ourselves to death, is to change our attitude. Unfortunately, this is probably the most difficult step as;

- attitudes are notoriously difficult to change
- we have to convince a majority of the world's population
- we have to convince those who have a high standard of living to consume less
- the amount of time in which to change attitudes is short

Ignoring for a moment the inherent difficulties of achieving these points, I see the following statements as being fundamentally flawed and demonstrating where we need to focus on changing our perspective.

The Earth is Infinite

While this is clearly an illogical statement, our actions and use of resources point to it being our default attitude. Consider for a moment the following examples:

- Supermarkets sell cutlery and plates made from plastic which are designed to be used once before being thrown away
- The cost of petrol (a finite resource) is currently at around $1.30 per litre, but the cost of milk (a replaceable resource) is $1.00 per litre
- We use plastic shopping bags and purchase water in plastic bottles
- Timber, imported from Malaysia, can be purchased from some hardware stores for a similar price to that of plantation pine
- On average Sydney households send 500kg of waste to landfill each year[21]

None of these things make sense if we understand that what the earth provides us has to be replenished. We have to change our decisions to be based on what will work over the very long term, rather than the short.

Growth is Good

"*our GDP increased by . .* ", "*growth in the last quarter was . . .*"

It is a mantra repeated continuously by politicians and by the media, 'Growth is Good'. Economic growth is the basis on which decisions are made, on which politicians are measured and on which our system runs.

But economic growth cannot occur indefinitely in a finite world. We have to develop new measures of success such as the United Nations Human Development Index which combines life expectancy, education and income and gives a greater overall assessment of how well the citizens of countries are doing.

The Measurement of Everything is in Dollars

When Nicolas Stern released his report on Climate Change in 2006 he measured both the cost of acting on climate change and the cost of not acting and presented these amounts as a percentage of GDP. While I understand why he did this, in reality, measuring in dollars the cost of not acting on such an event is unrealistic as the real cost is measured in the probability of the survival of our species.

Dollars, Yuan or Pesos are good when we are trying to compare the value of items which can be traded or exchanged. You cannot however, trade our existence against another item, especially when the other item, along with the concept of money, only exists while we do.

Instead of trying to measure everything in dollars we need to focus and think in terms of the actual outcome of our choices. When results are presented in this way, attitudes are more likely to be changed.

We Are the Most Important Beings on the Planet

"Will the earth survive?" was the headline. To most people this title is harmless enough, but what it illustrates to me is that once again we had elevated ourselves to the omnipotent position, of our species apparently being as important as the planet itself. In reality the planet will survive because it is a ball of rock and despite what we may like to believe, we are no more important to this planet than dung beetles and flies.

It would seem that this attitude is clearly rooted in our DNA, since this seems to demand that life forms be selfish if they are to survive in the wild. However when you are a human being, possess a knowledge of self and of the universe and 'the wild' consists of hitching your caravan to your SUV and driving to a campsite with running water, selfishness as a means to survive is a somewhat flawed concept. We must change our thinking so that we see ourselves as being 'a part of the planet not apart from the planet'.

We Can Engineer a Solution

While the actions of individuals at times would seem to bring into question the belief that human beings are intelligent, what is clear is that, as a species, we are absolutely brilliant at engineering. In 10,000 years we have managed to progress from stone tools to walking on the moon and driving machines around Mars! We can put hundreds of millions of electrical components on a piece of silicon the size of a fingernail and we can build dams so large that there is evidence to suggest that they may cause earthquakes[22]. Be it very small or very large and everywhere in between, we are very good at engineering a solution.

Unfortunately, while we have reaped marvellous benefits from this skill and associated knowledge, we have become so obsessed with this ability, that we now just expect it to happen. Furthermore, our past successes now mean that our general attitude to solving difficulties is to treat the symptoms, but rarely the root cause of a problem. We try desperately to maintain what we have and generally only consider changes which may benefit the accepted standard in the short term. Carbon capture and storage technology for coal fired power stations and the recent building of a desalination plant for Sydney are two examples of this short term thinking.

A Replacement for Fossil Fuels

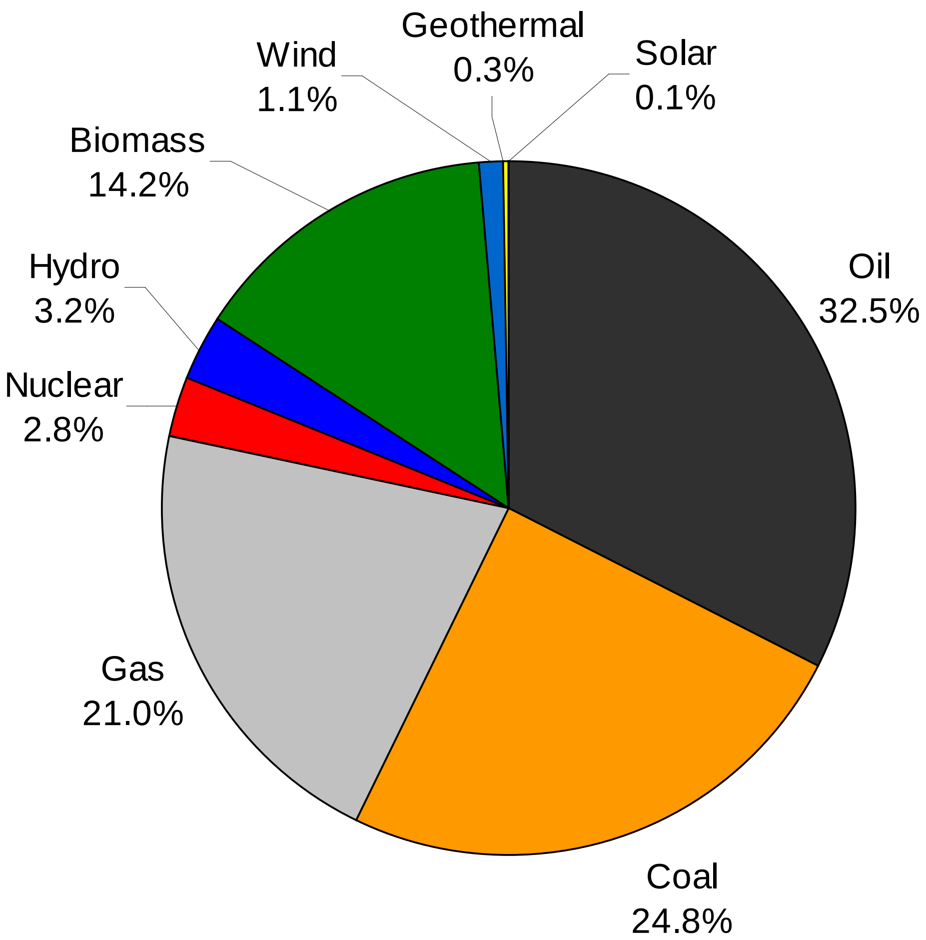
Apart from changing our attitude, we have another key problem to consider, that being that our single most important energy source, crude oil, is finite and will run out. If we do not prepare ourselves for this we run the risk of an economic and social catastrophe.

A discussion about energy alternatives, could easily take an entire paper in itself. So, in the interests of keeping things short, I will highlight the situation as it applies to the most common energy replacements based on current technologies.

Before discussing some of the alternatives, an argument as to why alternatives are required should be mounted.

According to statistics from BP, worldwide the amount of energy consumed in 2008, was 474 exajoules (474 x 10^{18}J) with the following diagram showing the sources of that energy.

Figure 16 – Breakdown of Worldwide Energy Sources[23]



Given that coal reserves are still significantly large that they are unlikely to run out in the short term, we have to find a replacement for the oil and gas we use, which currently accounts for 53% of the energy we consume. This is a significant amount of energy and given the earlier chapter about the likelihood that it will run out in the short term, alternatives are required.

Is it possible for us to find a replacement for the oil and gas we use? To answer this question, let us look at some alternatives and see what they could supply us.

Nuclear Energy

In the past couple of years, our previous concerns about nuclear energy appear to have decreased and it has started to be seen as an 'environmental friendly' energy source. This attitude appears to be based on the thought that it creates no carbon emissions[*]. However given that the waste products of the nuclear industry are lethal for longer than the period of recorded human history[±], this attitude seems to me to be akin to the idea that smoking is good for your health because it reduces stress levels.

Putting the radioactive waste argument aside, the current known recoverable resources of uranium amount to 5.4mt[24]. If all of this resource was converted, using current technology, to electricity it could replace oil and gas for only three and a half years.[#]

While there is little doubt that nuclear power will continue to supply us with a good proportion of electricity in the short term, it is not likely to offer us a realistic alternative to fossil fuels without significant technological advances.

Renewables

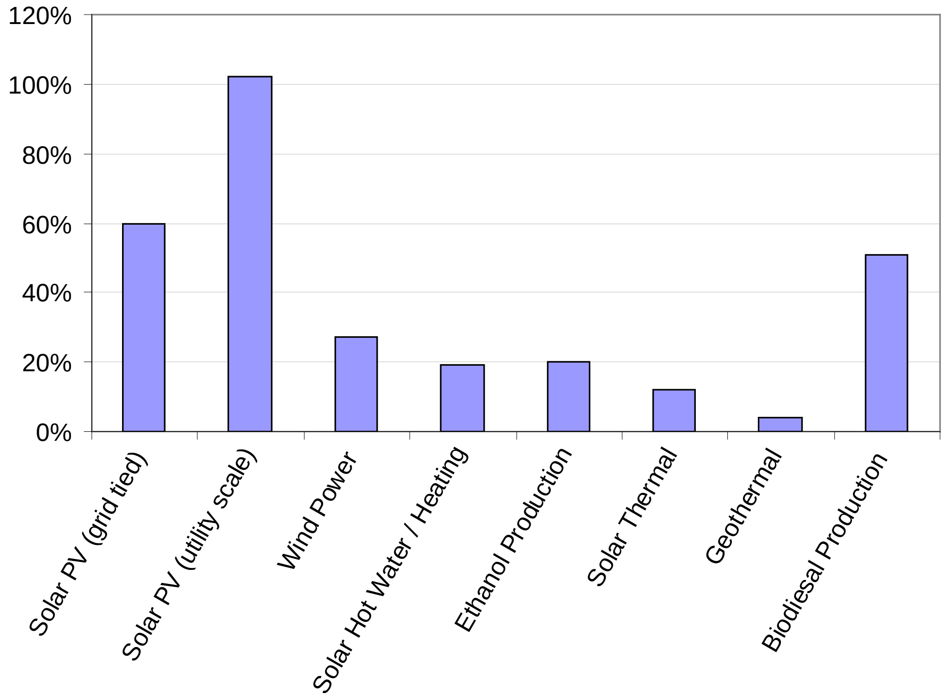
In the past 5 years there has been a considerable increase in the amount of electricity generated via renewable energy methods. This is clearly demonstrated by the following figure which shows the change in generation since 2004.

Figure 17 – Average Annual Growth Rates of Renewable Energy Sources (end 2004 - 2009)[23]

* Of course this assumption ignores the carbon dioxide emissions that are created by mining and purifying the Uranium, and in building the reactor itself.

± Plutonium-239 (Pu-239) has a half life of 24,110 years

\# See Appendix B for details



But to demonstrate the challenge of what is needed to replace oil and gas, consider the following.

If we were to replace all of the worlds use of oil and gas with solar cells, we would need to cover an area of 165,872 km^2* or in other words an area roughly two thirds the size of Victoria. If wind turbines are your preference, we would have to build 5,159,817[±] 5MW turbines (or approximately 110,000 off shore wind farms).

And these figures only cover the scenario that you want to replace the oil and gas we currently use. If you want to replace the coal as well then you have to add another 50% to these amounts. Furthermore, this amount doesn't take into account future projected population growth, it only covers what we currently use.

Future Technologies

When the topic of energy alternatives is raised often people will mention technologies which are yet to be fully developed, including, but certainly not limited to:

- developing a Hydrogen economy
- fusion reactors
- fast breeder nuclear reactors

For some of these technologies many millions of dollars and thousands of hours have already been spent without ultimate success. For others, no doubt developments over the next few years will lead to efficiency gains. But to believe that any of these will offer a realistic alternative to crude oil and gas, especially in the short term, would appear to be at best optimistic.

Conclusion

In recent years their has been a significant increase in the amount of energy generated from Solar, Hydro, Wind and other alternative sources and these increases have had significant benefits in cutting CO_2,

* See Appendix C for calculation details
± See Appendix D for calculation details

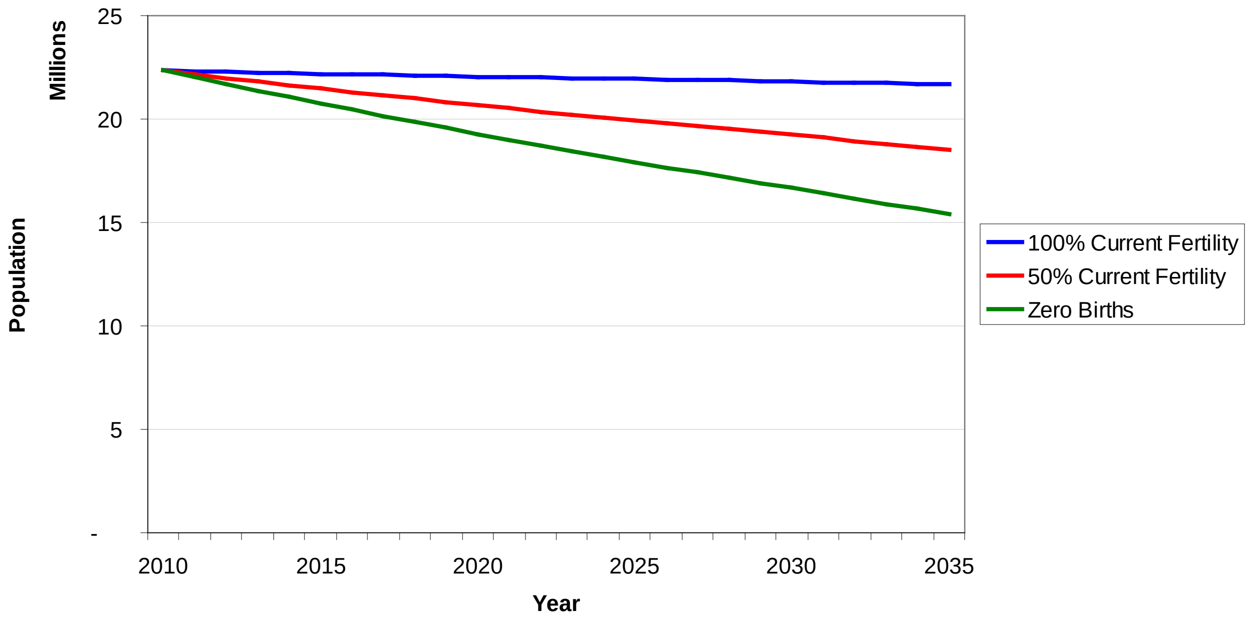
developing alternative energy companies and technologies, and changing peoples' attitudes. But despite this, the task of replacing crude oil and gas is monumental and to do so, we will have our work cut out for us.

Reducing our Population now

So what is the possibility of reducing our population? And how would this be done? History shows that there are many possible ways to reduce a population, but to avoid any unnecessary controversies; I will limit possible 'solutions' to those which concentrate on reducing the birth rate only.

The following graph however, demonstrates the difficultly in reducing the population solely on a reduced birth rate. Even if no births are assumed to occur the population still takes 15 years to reduce by 25%*.

Figure 18 –Australia's future population under different fertility scenarios



Government Incentives

Governments should remove all incentives that they currently offer which provide an incentive to have children. In Australia this would include removing;

- the baby bonus
- childcare rebates
- subsidies on IVF

Then, in a complete about face, the government should provide incentives not to have children such as;

- providing subsidies for vasectomy and tubal ligation procedures

* See Appendix E for calculation details

- maybe even introduce a 'childless rebate'

Education

Education is required in two areas.

Firstly, the population as a whole has to be informed of the problem we face. To make the necessary changes to the way we live, a foundation of general knowledge is required throughout the population on which attitudinal, social and structural change can be built.

Secondly, especially in developing nations, there must be an attempt to increase the education standards of girls and young women. It has been shown that more educated women have less children[25] and have more life options. With education comes independence and, ultimately, power - both in the community and at home.

Government Regulation

Where incentives to have less children do not have the desired effect, or further change is required, governments should consider regulating the number of children that couples have. China's single child policy, implemented in September 1980, has resulted in – according to the Chinese government - achieving 400 million fewer births in the past 30 years[26]. While many attack this policy as being against human rights, even in our society we give up certain rights for the greater good of the community. And, if by the greater good we mean avoiding civil breakdown, and maintaining enough resources to provide at least a minimum standard of living, then regulating the right to have children would be a positive.

Reducing our Resource Use

One of the requirements of maintaining economic growth is that we must continue to purchase goods and services. However, as has been discussed earlier, some of those goods are finite and will eventually run out. Working on the assumption that it is better if we try to avoid sudden changes to our way of living and allow us time to adapt, I believe the following changes give us the best possible chance of avoiding catastrophe:

Oil

The price of oil will undoubtedly rise in the next few years as:

- the world’s population increases
- China and India continue to develop and
- the supply of crude oil is constrained

In Australia, in order that we can cope with this change more effectively, we should consider;

- introducing a 5 to 10 cent per litre levy on petrol which increases each month
- removing incentives in the tax act which artificially decrease the amount paid for fuel
- refusing to build any more major arterial roads
- introducing a certification system such that each adult is given a fixed amount of petrol at the start of the year, such that any surplus from those who don’t use their own allocation could be traded on an open market.

Consumption

Providing methods to reduce our consumption are many and varied. The following ideas concentrate on the packaging that items come in and include;

- introducing deposit bottle, or possibly, deposit packaging systems whereby consumers who return packaging for its reuse are rewarded
- with the exception of medical equipment, legislate for the reduction or elimination of single use plastic packaging (e.g. plastic shopping bags)
- ban any packaging which is non-recyclable (e.g. polystyrene) and not biodegradable

With respect to the products that we purchase we could start by removing the best before date from food packaging. Most consumers assume that this means that food after this date can no longer be eaten and is disposed, when in reality it is still edible.

A more radical suggestion to reduce consumption would be to impose a consumption tax on goods when they are purchased. The amount of tax payable on an item could take into account

- the cost of recycling the item at the end of its lifetime
- the material used to make the product and
- the expected product life time

Consequently, consumers would be rewarded for buying products which have a long life, and which are built from materials which can be recycled. Furthermore any funds raised could be applied to improving recycling systems to maximise recovery and eliminate landfill. Additionally, consumers would not have to bear any disposal costs, since these were paid when the item was purchased.

Increasing the fees payable for kerbside waste collection or the amount payable when items are taken to the tip do not offer a plausible solution to reducing consumption. This is because:

- people don't relate the additional cost at the time of disposal to their consumption because of the time lag and
- people are able to avoid paying these fees, which they may perceive to be exorbitant by the dumping of rubbish.

Energy

With crude oil supplies likely to become exhausted in the short or medium term and with the use of coal leading to global warming, alternative energy sources have to be found. In order that a transition to these other sources is as manageable as possible and so that we can develop and maintain a renewable energy sector we should:

- insist that all new homes include solar hot water and solar PV systems
- provide profitable long term incentives for existing home owners to install solar PV and hot water systems on their homes[†]
- constructing solar thermal base load power stations as an alternative to coal
- insisting on energy efficient insulation to be applied in all new housing with well planned incentives to retrofit existing houses

It is true that some of these schemes have already been introduced or are currently being run by different governments within Australia. However, the Federal Government's insulation scheme and the New South Wales government's solar scheme are two examples where the funding, planning and implementation appear to have suffered from short term thinking and this has been detrimental to the industries that they initially aided.

Final Thoughts

In all my readings (and watchings) to compile this paper, the following passage from a paper by the noted author, Professor Jared Diamond[11], about Rapanui (Easter Island) and its inhabitants, best sums up our current situation as I see it.

"By now the meaning of Easter Island for us should be chillingly obvious. Easter Island is Earth writ small. Today, again, a rising population confronts shrinking resources. We too have no emigration valve, because all human societies are linked by international transport, and we can no more escape into space than the Easter Islanders could flee into the ocean. If we continue to follow our present course, we shall have exhausted the world's major fisheries, tropical rain forests, fossil fuels, and much of our soil by the time my sons reach my current age.

Every day newspapers report details of famished countries-- Afghanistan, Liberia, Rwanda, Sierra Leone, Somalia, the former Yugoslavia, Zaire--where soldiers have appropriated the wealth or where central government is yielding to local gangs of thugs. With the risk of nuclear war receding, the threat of our ending with a bang no longer has a chance of galvanizing us to halt our course. Our risk now is of winding down, slowly, in a whimper. Corrective action is blocked by vested interests, by well-intentioned political and business leaders, and by their electorates, all of whom are perfectly correct in not noticing big changes from year to year. Instead, each year there are just somewhat more people, and somewhat fewer resources, on Earth.

It would be easy to close our eyes or to give up in despair. If mere thousands of Easter Islanders with only stone tools and their own muscle power sufficed to destroy their society, how can billions of people with metal tools and machine power fail to do worse? But there is one crucial difference. The Easter Islanders had no books and no histories of other doomed societies. Unlike the Easter Islanders, we have histories of the past--information that can save us. My main hope for my sons' generation is that we may now choose to learn from the fates of societies like Easter's."

Appendix A – Population Growth Curves

The curve described in this paper, $P_t = P_0 exp^{rt}$, was chosen to demonstrate as simply as possible an exponential curve.

However it has been argued that population growth, is more accurately modelled using a logistic curve as this incorporates a feedback mechanism to reduce growth as resources are reduced or, in other words, the birth rate is proportional to the number of existing lives and the available resources.

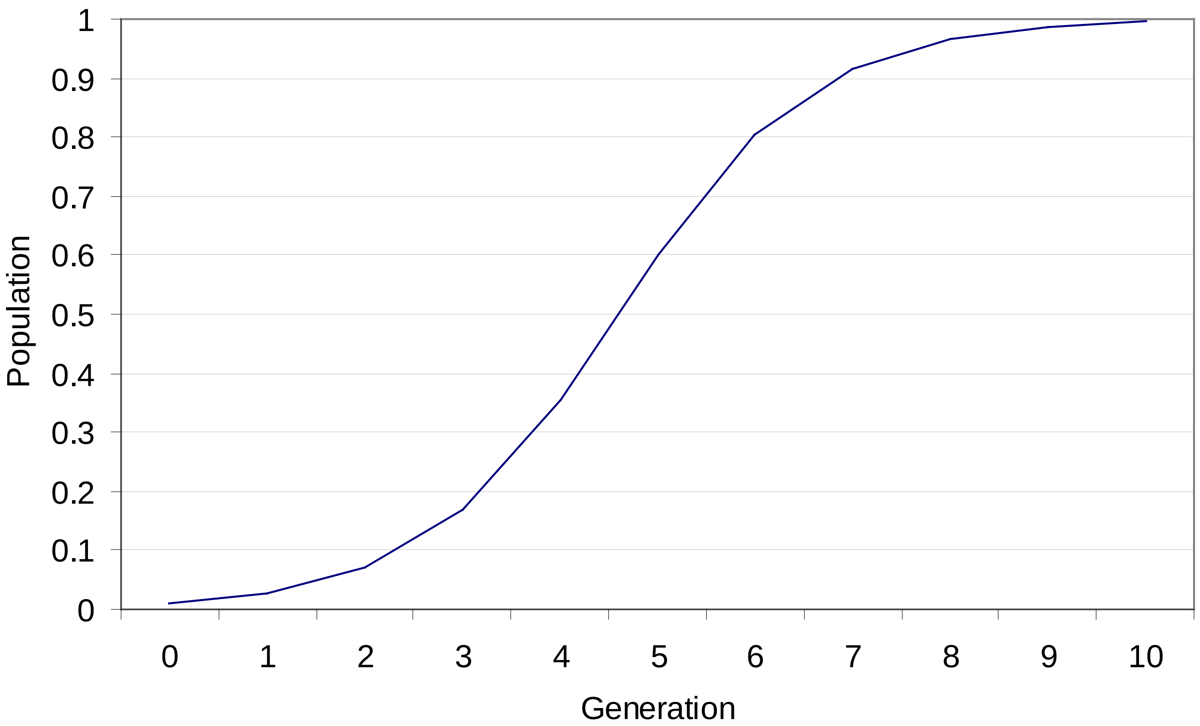
A logistic curve is represented by the functional equation

Pt = 1 / {1 + (1/ P0 -1)e-rt)}

where r is (normally) a positive constant.

The function produces a curve shaped like the following.

Figure 19 – Logistic Curve (P(0) = 0.01, r = 1)



It is true that there are a number of examples where introduced species have increased their population size and then managed to stabilise their population, and in these cases their population curve would be similar to that shown above.

For the human species, if we are able to grow enough food and continue to get enough energy then it is likely that our population will plateau in a similar fashion. The problem however is not the ultimate shape of the curve but that the curve is being supported by resources which are either finite or which are not being replenished fast enough.

Appendix B – Years of Coverage If Uranium were to replace Crude Oil & Gas[27]

To determine the number of years that uranium could supply us with the current energy that we get from crude oil and natural gas, we have to determine the current energy that oil and gas provide, the amount of energy derived from nuclear reactors per kilogram of uranium and the total amount of uranium available.

1. Firstly determine the total energy that is required to be generated

Current Worldwide Energy Use	4.74×10^{20} J	(1)
Converted to kWh	1.32×10^{14} kWh	(2) = (1) / (60 x 60 x 1000)
Proportion of current use which is oil and gas	51.5%	(3)
Gives total energy to be replaced	6.78×10^{13} kWh	(4) = (2) x (3)

2. Determine the amount of uranium required to run a nuclear reactor and the energy generated

Annual Uranium required to run a 1GW nuclear reactor	170 t	(5)
Energy produced from 1GW reactor per annum	7.5 TWh	(7) = (5) x (6)
Convert to kWh	7.5×10^{9} kWh	(8) = (7) x 10^9

3. Calculate how much energy can be generated from known reserves

Total recoverable reserves[‡]	5.4 mt	(10)
Total energy from reserves	2.38×10^{14} kWh	(11) = (10) x (8) / (5)
Number of years coverage	3.5 years	(12) = (11) / (4)

[‡] This is the total known reserves up to a recoverable price of USD130 per tonne. Reserves will increase in size if deposits requiring more expensive mining are included.

Appendix C – Replacing Crude Oil & Gas with Solar (PV) Cells

To determine the area required to be covered in solar PV cells in order to replace our current use of crude oil and natural gas, we have to divide the total energy required by the energy that can be generated per metre (or kilometre) square of PV cells.

1. Firstly determine the total energy that is required to be generated

Current Worldwide Energy Use	4.74×10^{20}J	(1)
Converted to kWh	1.32×10^{14}kWh	(2) = (1) / (60 x 60 x 1000)
Proportion of current use which is oil and gas	51.5%	(3)
Gives total energy to be replaced	6.78×10^{13}kWh	(4) = (2) x (3)

2. Determine average generation from PV cells per square metre

Average Total Solar Irradiance (TSI)[§]	1.35 kW/m^2	(5)
Reduction due to atmospheric reflection (approx)	30%	(6)
Average energy from sunlight at the Earth's surface	0.95 kW / m^2	(7) = (5) x [1 – (6)]
Average sunny days per annum	70%	(8)
Average hours of sunlight per day	8 hours	(9)
Total hours of sunlight per annum	2044 hours	(10) = 365 x (8) x (9)
Total power available at surface per annum	1.93 kWh / m^2	(11) = (7) x (10)
Efficiency of solar cells	20%	(12)
Total energy production from solar cells (per m2)	408.8 kWh / m^2	(13) = (12) x (11)
Total area required	1.66×10^{11} m^2	(14) = (4) / (13)
Convert to km2	165,872 km^2	(15) = (14) / 1000^2

Further Reading
http://www.ucsusa.org/clean_energy/technology_and_impacts/energy_technologies/how-solar-energy-works.html
http://earthobservatory.nasa.gov/Features/EnergyBalance/page2.php

[§] TSI is the average amount of energy per unit area received by the Earth at the top of the atmosphere.

Appendix D – Replacing Crude Oil & Gas with Wind Turbines

To determine the number of wind turbines required to replace our current use of crude oil and natural gas, we have to divide our total energy requirement by the energy that can be generated from each turbine.

1. Firstly determine the total energy that is required to be generated

Current Worldwide Energy Use	4.74×10^{20} J	(1)
Converted to kWh	1.32×10^{14} kWh	(2) = (1) / (60 x 60 x 1000)
Proportion of current use which is oil and gas	51.5%	(3)
Gives total energy to be replaced	6.78×10^{13} kWh	(4) = (2) x (3)

2. Calculate the average amount generated by each turbine (5MW)

Turbine size	5 MW	(5)
Turbine efficiency	30%	(6)
Energy generated per annum	13.1×10^{6} kWh	(7) = (5) x 365 x 24 x (6)

3. Combine to determine number of turbines required

Total number of turbines required	5,159,817	(8) = (4) / (7)

Further Reading
http://www.bwea.com/edu/calcs.html
http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file17821.pdf

Appendix E – Australian Population Projection

The population projection used to produce the graphs is a very simplistic model developed for the sole purpose of demonstrating the effect that the fertility rate has on the total population.

To create the model the following formula were used:

$$\text{Births}_{(\text{year, sex})} = \text{SUM}_{(\text{age - 1 = 15 to 49})} \text{ Fertility Rate}_{(\text{age - 1})} \times \text{Lives}_{(\text{year - 1, female, age - 1})} \times \text{Sex Proportion}_{(\text{sex})}$$

$$\text{Deaths}_{(\text{year, sex, age})} = \text{Death Rate}_{(\text{year, sex, age})} \times \text{Lives}_{(\text{year - 1, sex, age - 1})} \quad (\text{for age} >= 1)$$
$$= \text{Death Rate}_{(\text{year, sex, age})} \times \text{Births}_{(\text{year - 1, sex, age - 1})} \quad (\text{for age} = 0)$$

$$\text{Lives}_{(\text{year, sex, age})} = \text{Lives}_{(\text{year - 1, sex, age - 1})} - \text{Deaths}_{(\text{year, sex, age})} \quad (\text{for age} >= 1)$$
$$= \text{Births}_{(\text{year - 1, sex, age - 1})} - \text{Deaths}_{(\text{year, sex, age})} \quad (\text{for age} = 0)$$

These formula ignore both immigration and emigration and the interaction of births and deaths acting continuously. The formulae also assume, that births and deaths act independently rather than dependently as is the case in reality.

The assumptions for the model are from the Australian Bureau of Statistics and are listed in the endnotes[28].

Examining the initial results from the model showed that if the current fertility rate of 1.9 births per 1000 people was maintained the population would grow. However, the ABS reports that the replacement fertility rate for Australia is 2.1 which implied that the model was overstating the future population to some degree.

To remove this assumed error, the results from the model were then scaled so that with a fertility rate of 2.1 the population remained constant.

Despite this initial inconsistency, and the simplistic methodology, the graph is still fit for its purpose of showing the run off in the population over time and the impact that the fertility rate has on the total population.

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Historical Estimates of World Population
United States Census Bureau
http://www.census.gov/ipc/www/worldhis.html

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The Twentieth Century Atlas
Matthew White
http://users.erols.com/mwhite28/warstat8.htm#TotalEst

While the historical estimates of the number of deaths from wars varies, the analysis on this website is very comprehensive.

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The Influenza Pandemic of 1918
Stanford University
http://virus.stanford.edu/uda/

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The Introduction, Increase, and Crash of Reindeer on St. Matthew Island
David R Klein
Alaska Cooperative Wildlife Research Unit
University of Alaska
http://dieoff.org/page80.htm or
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