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Supervised Project Report
(ANTA604)

Fossil Fuel Reliant Energy in the Production and Consumption of Resources at Scott Base

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Abstract/executive summary :
In December of 2015, the Inter-Governmental Panel on Climate Change (IPCC) Paris meetings announced a commitment to restrict global climate change increase to 1.5%. Much of the scientific information that informed this decision came from research executed in Antarctica.
It is now widely accepted amongst the scientific community that the main cause of climate change is from human activity – primarily the burning of fossil fuels. Our current lifestyle patterns, which we seem intent on increasing as a mark of success will have a dramatic, undesirable effect on the environment in which our great grandchildren will be expected to live.
Reflecting the its obligations under the Antarctic Treaty and the Madrid Protocol, Antarctica NZ (ANZ) statement of intent shows its commitment to "…the highest standards of international environmental stewardship through our efforts to minimise environmental footprints…". Due to the remote and extreme characteristics of the Antarctic environment, human activity in Antarctica is highly dependant on fossil fuel for both transport and generation of essential utilities such as water, heat and electricity.
The volume of fuel consumed is dependant on the activities we do (how we do it and how much we do of it), and the mechanical efficiency in which we do them. Largely, the efficiency aspect is based in technology, which is financially, logistically and environmentally expensive to improve and often yields relatively small incremental improvement. Improvements from the activities we do and how we do them is much more flexible, can yield fast results, may be surprising cheap to obtain and yield a relatively large return.
This report reviews the energy related initiatives at Antarctica NZ's Scott Base on Ross Island and suggests a program that, if developed, could make the NZ Antarctic program a world leader in pro-active and effective carbon foot print reduction. A possible funding structure is also, suggested, that responds to varying year by year demands.

Executive Summary

The financial and environmental costs of running an Antarctic program are directly linked through the burning of fossil fuel (predominantly AN-8, a cold environment derivative of Jet A-1 fuel). We are in a time that appropriate financial control and environmental management is of key importance. There are 2 sides of this linked cost situation, the production side, and the consumption/demand side of resources when considering management initiatives.

Production Side

Systemic Changes (Wind Farm, Ross Island Energy Grid (RIEG) and Generator Automation) – tends to offer large savings but requires large investment and logistical planning

Technology Changes (efficiency upgrades e.g. lighting) – often has knock on effect within system, minimising actual gains. Savings often minor and with additional (often unexpected) associated costs.

Consumption/Demand Side

Essentially, demand is a reflection of people's attitude and how they behave regarding resource use.

Using recognised Demand Side Management techniques, improvements can be fast and 'painless' to achieve and continual return if input is maintained with small but careful effort.

Very low cost to initiate, resource reduction of 20-50% have been achieved, depending on the resource.

Initiation of resource use awareness can grow to become a part of the general holistic cultural attitude.

Findings Summary

Note All figures exclude resistance and network loss – representing only the level of electricity produced or consumed. All workings can be found in following sections. Verification of the source data may influence the results (by Antarctica NZ engineers/environmental managers, although probably not significantly.

Production Side Initiatives

Production – Wind Farm

Both the financial savings and reduction of total CO_2 equivalent emissions (tCO_2e) of the energy produced by the Wind Farm contributes to the Ross Island Energy Grid can be measured, and is considered to be a part of the Antarctica NZ contribution in the shared logistics program with the United States Antarctic Program (USAP). For the 2014/15 year, the Wind Farm produced 2,331,895 kWh. The associated carbon emission reduction was 1,663 tonnes and a financial saving from unburnt fuel of $1,309,936 (based on an AN-8 price of $2 per litre (landed)).

Production – RIEG Generator Automation

Using publically available diesel consumption figures for diesel generators, the fuel savings from the integrated operation of the Scott Base and McMurdo Station generators was estimated. Based on 2 hours per day, the optimised running may be reducing fuel burn of 20750litre per year, with emission reduction of 53 tonnes per year and financial savings of $41,501.

Summary of Production Side Initiatives

Production Savings of these 2 initiatives can be summarised as in Fig.1.:

Production Side Savings				
Wind Generation	Financial Savings at $2/l		$1,227,644	NZ
	tCO2e Savings		1,559	tonne
Generator Optimisation	Financial Savings at $2/l		$41,501	
	tCO2e Savings		53	tonne
Total Production Cost Savings			$1,269,144	
Total Emissions Savings			1612	tonne
2014 Scott Base AN-8 Related Emissions	953	tonnes or	169%	of 2014 Levels
2014 Total Emissions	4,229	tonnes or	38%	of 2014 Levels
Comparison to 2014 Usage in order to show degree of relative savings only				

Fig 1. Production Savings

Financial investment and emission production have not been considered in this exercise, although should be for accurate assessment. The financial investment was approximately $12M in 2008 and to my knowledge, the related emissions production has not been estimated. A proper back-costing is a recommended activity that would hold value especially for bases considering refurbishment of their electrical production facilities.

Demand Side Initiatives

While Scott Base management are very aware of opportunities for improving the efficiency of the base infrastructure (e.g. re-purposing energy in heat dump events), the culture focused activity (initiated by the 2008 Sustainability Energy Protocol Package (SEPP) program and extended from there) has shown to yield worthy results. Actual usage levels and associated savings (and an identified are of potential gain) can be summarised as below:

		Year of Comparative Data									Per Bed Night Savings	
Area		2008	2010	2011	2015	Reduction	AN_8 per L/Unit	Savings Per Bed Night	$/Unit	(Kg) tCO2e per Litre AN-	$ Savings	tCO2e Savings (Kg)
Power	kWh/ bed-night			81.8	71.9	10	0.174	1.73	$ 2	2.54	$ 3.46	4.40
Water	Litres/bed night	150			102.5	48	0.049	2.33	$ 2	2.54	$ 4.66	5.91
Waste (Freight)	kg/bed-night		1.60		0.6	1.0	1.2	1.22	$ 2	2.54	$ 2.44	3.10
Waste (Sterilisation)	$/bed-night		$1.55		$1.11	$ 0.44		$ 0.44			$ 0.44	
											$ 10.99	13.40
								Bed Nights in 2015			13,374	13,374
								Est. Annual Savings			$ 146,990	179,246
								tCO2e Savings Tonne				179.25
								2015 tCO2e from AN-8				953
								Reduced Consumption as % of 2015				19%
	Potential Savings From Reducing Inside Temperature by 2 degrees								$ Per Year		$ 13,253	
	(Currently approx 20?) (see workings below)									tCO2e Tonne Saving		16.83
						Total (Historic Plus Potential Heat Savings)					$ 160,243	
												196.08
						Total Reduced tCO2e as % of 2015 Levels						21%

Fig 2. Summary of Demand Side Initiative Results

To note, each of the areas can look insignificant, they added together (if inside heat were to be adjusted), they would decrease AN-8 related emissions by 25% and add over $160,000 in additional AN-8 fuel (at $2 per litre) on top of 2014/15 levels.

These are annual savings, and have been achieved with little investment, other than careful thought, analysis and regular feedback/information in order to it become a part of the current culture.

However, a more considered and widespread program may continue to yield further benefits, knock on awareness onto other areas and the culture in general should be recognized.

See report body for discussion on initiatives and resulting year by year results.

Areas of Opportunity

National Antarctica Programs (NAP) that are due for refurbishment could do well to consider a structured demand side initiative program to create a resource aware culture <u>prior</u> to determining demand requirements for base design. Continent wide collaboration and information sharing would yield both financial and environmental benefits for all involved. The single area of greatest cost and consumption by far is inter-continental Antarctic bound travel. Although beyond the scope of this report, even small improvement in inter-continental logistical efficiencies would be significant in comparison to Antarctic based energy use.

The awareness of the production of resources on Ross Island is pivotal to the on-going cultural maintenance. The pre-season training and base orientation are the ideal times to introduce this aspect to both returning staff and new comers. Some of the resources found in the appendix of this report could be developed into useful tools to help with the delivery and integration of awareness initiatives as well as to act as information displays on base.

A more comprehensive list of opportunities is included in the report; however, a structured initiative program is suggested.

Note: There is a pattern that hints at an optimal occupancy level for Scott Base in terms of resource use that is higher than present levels. This level has not been investigated and achieving these levels would obviously increase intercontinental logistical activity.

Areas of Threat

We are currently at a time of very low but fluctuating fuel prices. It is not unreasonable to prepare for fuel price to double or even triple over the next few years. Base running costs aside (see report appendix for costings for various fuel price changes), travel related fuel burn is the greatest single financial and environmental cost to Antarctic programs, and wide spread aggressive reduction programs to travel volume or improve efficiencies/effectiveness may be appropriate. Shortened ice run way seasons have a significant impact upon travel related costs and emissions as the more efficient jets cannot be used. This creates a significant management variable that could benefit from alternative strategies.

Possible Funding Structure

Antarctica NZ is currently operating under a frozen budget, yet is being asked to support more science programs, the funding and the expectations are not in align with each other or in align with expectation of the organisation to successfully support leading science programs. At a time that the scientific information that comes out of the supported programs is so critical to understanding our environmental situation, this seems illogical. Scott Base In a very simplistic sense, Scott Base has relatively fixed operating expenses (varying mostly with AN-8 price) and over the routine staffed operations the number and type of scientific programs that are supported whose crude variables are the number of personal involved and the distance/transport mode from base). This defines 2 silos within the one organisation – base operations and field support.

A funding model based upon the 2 silos may look like this

Annual Fund = (Base Budget + Field Support Budget) * Fuel Price Variable

Where the Base Budget is relatively constant, but the funds for the Field Support Budget arrives with notification of the approved science programs etc.

Summary

Antarctica NZ has been proactive in initiating cost and emission reduction programs in their management of both Scott Base and head office in Christchurch. While prepared for a future of challenged budgets, requests for increased activity, variable fuel prices and increasing need for more aggressive reduction of GHG gases, Antarctica NZ has a number of areas of potential savings available, and a wide spread, managed program would continue to yield increased returns. Such a program would position them well as a role model, globally, and as an illustration of potential savings for other National Antarctic Programs. A continent wide study could certainly yield results on identifying and quantifying the best management practices. Such work would fit well within the expectations of the Antarctic Treaty and associated documents and in line with the actions required if the 2015 IPCC ambitions are to be met.

Introduction

In both financial and environmental terms, Antarctica is an expensive location to establish and run populated bases due to the isolation of distance and extremity of environment. Over time, man's way of operating there has shifted from explorative and exploitive to one of inquiry and stewardship, thanks in part to the requirements of the Antarctic Treaty and the Protocol for Environmental Protection (the Madrid Protocol).

More recently man's growing awareness of his impact on the globe (primarily through the emission of Greenhouse Gasses (GHG's) as a by-product of burning of fossil fuels) from which is culminating in global warming that threatens the very way we have become accustomed to exist. This is a very strong statement that our existing lifestyle is not sustainable. Possibly the most important information that comes from Antarctic science telling us of the historic climatic states, as well as the current state and plays a critical role in allowing us to predict the uncertain, but inevitable climate we will face.

The way that National Antarctic Programs (NAPs) are run has changed over time. From the hard early Heroic Era, a pioneer town culture emerged which has evolved to a point that today's newly established bases strive to reach a Zero (carbon) Emissions (e.g. Belgium's Princes Elisabeth Station). Currently, the permanently manned stations (and most of the older summer stations) have a very high, if not total, reliance on fossil fuel energy for generating electricity, heat and powering transport.

Established bases have a harder time to reach such standards as they are limited by constrains of the existing infrastructure and the logistical cost of infrastructural upgrade is significant. It is possible, that for many of these established bases, that the greatest returns may be had for relatively minimal investment, and should be pursued PRIOR to thoughts or designs of base upgrade as substantial savings may be achieved in establishing a culture that willingly requires a lower level of resources, and as such, requires less investment in infrastructure.

The primary fossil fuel source of energy for Ross Island is AN-8, a winterised version of military aviation fuel that has a freezing point of -46 °C (Antarctica NZ 2015) . As CO_2 is a by-product of burning fossil fuels, reducing the volume of fuel a base consumes reduces both the CO2 emissions AND the cost of the fuel required to produce the resource.

The link between fuel use and carbon dioxide emissions is direct. For every litre of AN-8 that is burnt (or Jet A1 or any of its derivatives there is about 2.54 kg of CO_2 emitted as an invisible, odourless gas.

In the process of assessing the data provided by Antarctica NZ, it was very clear 2 distinct aspects of resources come into play – the production side, and the demand or consumption side.

Before starting to discuss these 2 aspects, it is important to provide the history of Scott Base, as it illustrates the evolution of the current base as an engineering system.

The History of Scott Base

Originally constructed to support the British Trans Antarctic Expedition (TAE) and the International Geophysical Year (IGY), Scott Base was established on Pram Point on Ross Island in the Ross Ice Shelf in 1957. Today, Scott Base can host up to 85 people in summer, and routinely accommodates 10-15 winter over staff. Currently operated by Antarctica New Zealand, a department of the New Zealand Government, New Zealand has held a permanent presence ever since – an accomplishment that is regarded as critical for NZ to retain its right to land claim under Antarctic Treaty System (ATS). The maintenance of this presence is regarded as so important that it is written into the Mission Statement of Antarctica NZ.

The Scott Base is primarily constructed of elevated units built of polystyrene and aluminium sandwich and connected by corridors – allowing safe, sheltered access to all parts of the building regardless of the time of year or weather conditions. Such a design means that the base has well-organised, tidy appearance with all interconnected services running below the flooring.

The standard of Scott Base has upgraded over time as the base demands have changed and as technology has allowed innovative alterations have occurred. Often, due to logistics and scale of a project, time frames often over lap and stretch out over a number of years. Below is an approximate time line:

- 1956-57 Constructed to support NZ activities for the International Geophysical Year (IGY) in 1957/58 and Trans-Antarctic Expedition.
- 1959 The base was signed over to NZ
- Rebuild program 1970's – 80's
- 2003 Environmental Management Plan Initiated (Aims: "To run Scott Base as a leading environmentally sustainable small research base in Antarctica" and to reduce fuel usage by 10%
- 2005 Hillary Field Centre (HFC) building to stage events from. Prior to this, staff worked in an unheated hanger constructed in 1960.
- 2005 Meridian assess Ross Island for suitability for wind turbine power generation
- 2005-2012 Building Management System installed throughout Scott Base.
- 2008 Established as a base year with a 5-year plan to reduce carbon emissions by 28%
- 2008 Ross Island Wind farm installation started (3 turbines with 0.99 MW capacity) / Commissioned in December 2009. (see further note below)
- PADS (Public Area Display System) TV monitors in the mess hall to post public information, although this is not currently used for resource related information.
- By 2014, carbon emission had been reduced by 23% from the base year 2008/9 – of which the wind farm was the single biggest contributor.
- 2014 Automated generator management as part of the Ross Island Energy Grid (REIG)
- 2014/15 Energy Dash board initiated in order to monitor the key metrics of energy output, fuel use, costs and carbon emissions for the electrical and thermal energy systems of Scott Base.
- 2015 HFC extensive refurbishment and laboratories installed

Other initiatives from 2003-2009 include:

- Improved management of the vehicle hitching rail system
- Conversion of kitchen appliance heating from electricity to gas.
- Installation of additional window glazing (from double to quadruple).
- Installation of energy efficient lighting at Scott Base (T5 technology).
- Installation of waterless urinals.
- Closure of the hydroponics unit at Scott Base.
- Installation of motion detectors for lighting in some buildings.
- Reduction in the Scott Base vehicle fleet size.
- Removal of high waste items such as corn on the cob.
- Focus on reduced generation of food waste
- Removal of excess packaging on items prior to transport south
- The installation of self contained engine heating units in replacement vehicles is reducing the reliance on the Hitching Rail for ensuring vehicle availability during cold periods. This replacement program is on going.

Notes Regarding Innovations

- **The Ross Island Energy Grid (RIEG)**: In order for the wind farm to be of a viable scale, the energy needed to be shared with McMurdo Station– initiating what eventually became RIEG. One of the challenges with wind power generation, is that, as power is generated dependant upon the wind strength, it requires the system to be able to compensate for excessive/insufficient wind generated power. McMurdo's has four 1400kW generators and a 1200kW generator (net 6800kW), while Scott base has three 180 kW generators (net 540 kW). With the Wind Farm's 990 kW capacity, the RIEG generation capacity is 8330kW.
- **Wind Farm**: It was expected to reduce fuel burn by approximately 463,000 litres per year and reduce Greenhouse gas (GHG) production an estimated 1,242 tonnes of CO2 per year. In the 2014/15 year it generated 2,331,895 kWh which would have required an estimated 613,822 litres of AN-8 which would have produced 1,559 tonnes of tCO_2e. The 2014/15 electrical consumption of Scott Base was 961,497 kWh – about 41% of the power generated by the Wind Farm. The remaining power is accepted by USAP as part of the logistic sharing agreement (see below for estimation of savings and value).
- 2009 Initiated Carbon Emissions Management And Reduction Scheme (CEMARS) in order to measure and manage carbon emissions in line with ISO 14064–1.
- Automation of the Scott Base generators means that Scott Base has no control when the generators operate. The purpose of McMurdo controlling the generators is to optimise the efficiency of the generators to more closely match the electrical load requirements. Associated savings are calculated below.

  The power generation in the RIEG can be represented diagramatically as in Fig 3. Ross Island Electrical Generation Diagram

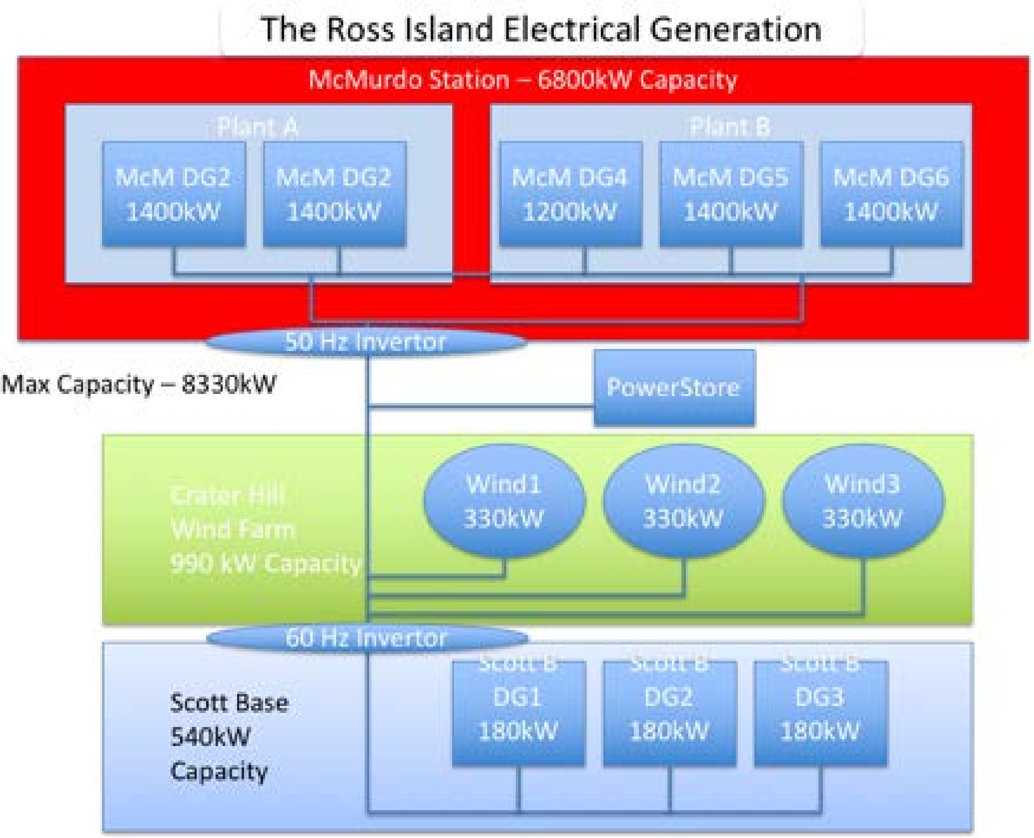


Fig 3. Ross Island Electrical Generation Diagram

The Environment/Infrastructure/Culture Interface

In considering base and infrastructure design, there are 3 groups of considerations:

1. <u>What the environment demands in order to arrive and survive.</u>

The environment determines what is needed in order to survive. The extremity of the environment demands that there is shelter – however, above a certain existential point, the level is negotiable. Other facets of environmental demands are warmth, food and water (biological) and transport (due to remote location).
At levels below what is <u>needed</u> lead to no presence in Antarctica or death (as illustrated so dramatically during the Heroic Era).
Providing these aspects are non-negotiable.

2. <u>What people *want* or expect and the culture allows.</u>

This category is more about comfort levels, is negotiable (and possibly strongly fought) and is highly flexible.

3. <u>What is provided.</u>

This is determined in the design and establishment of the base and its infrastructure. Semi flexible over time (outside its operating parameters) and changes typically have substantial costs associated with them. The resources provided can influence what is accepted due to simple availability.

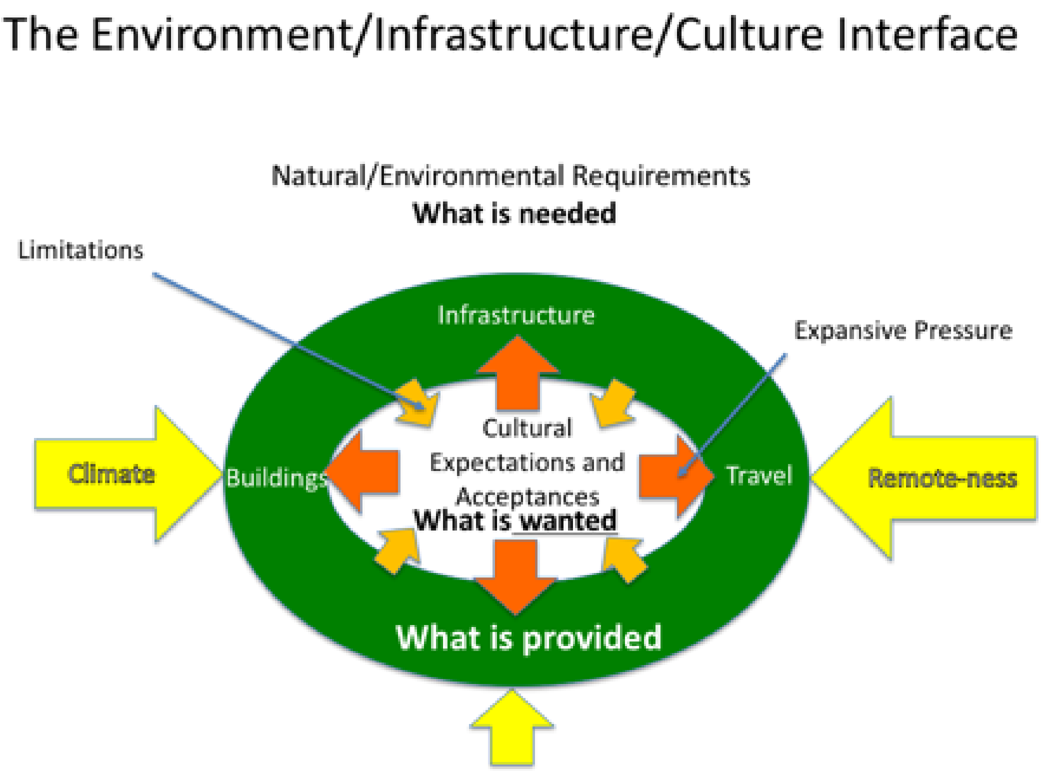


Fig 4. Environment/Infrastructure/Culture Interface Model.

The second category (Cultural Expectations) is can be regarded as a spectrum and is an aspect that can be a management aspect in terms of the culture of the base.

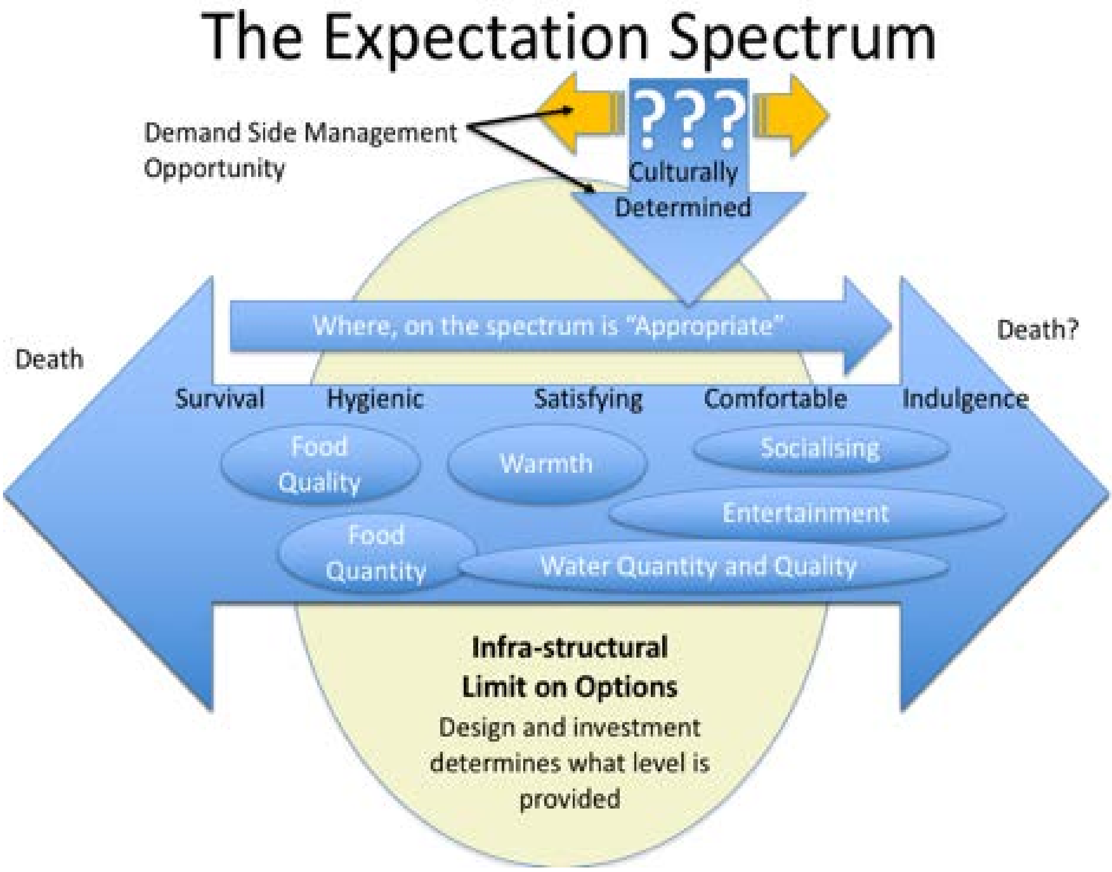


Fig 4. The Expectation Spectrum

Background Information on Resources in the Antarctic Context

The following provides some context of resource use and provision in the Antarctic environment.

1. Water – due to the extremely low temperatures and dry climate, clean, potable running water is extremely scarce in Antarctica. Generally, the uses of water include drinking, food preparation, hygiene and cleaning, science, fire fighting. As a rule, the only places water can be obtained from in Antarctica is from the snow or the sea (desalinisation or reverse osmosis processes). Not only is the production of water unique, but environmental consideration and ATS requirements means that what cannot be treated and appropriately returned to the environment, most be removed from the continent. Because of requirements of the Ministry of Foreign Affairs and Trade in NZ, the treated solids of human waste from the Waste Water Treatment Plant (WWTP) is sterilised upon arrival in Christchurch prior to being shipped to the Kate Valley Land Fill in North Canterbury. (see The Scott Base Water Flow Chart (2015)).

   The water cycle involves a number of stages, many of which are dependant on energy from fossil fuels, as the fig 5 The Scott Base Water Process illustrates.

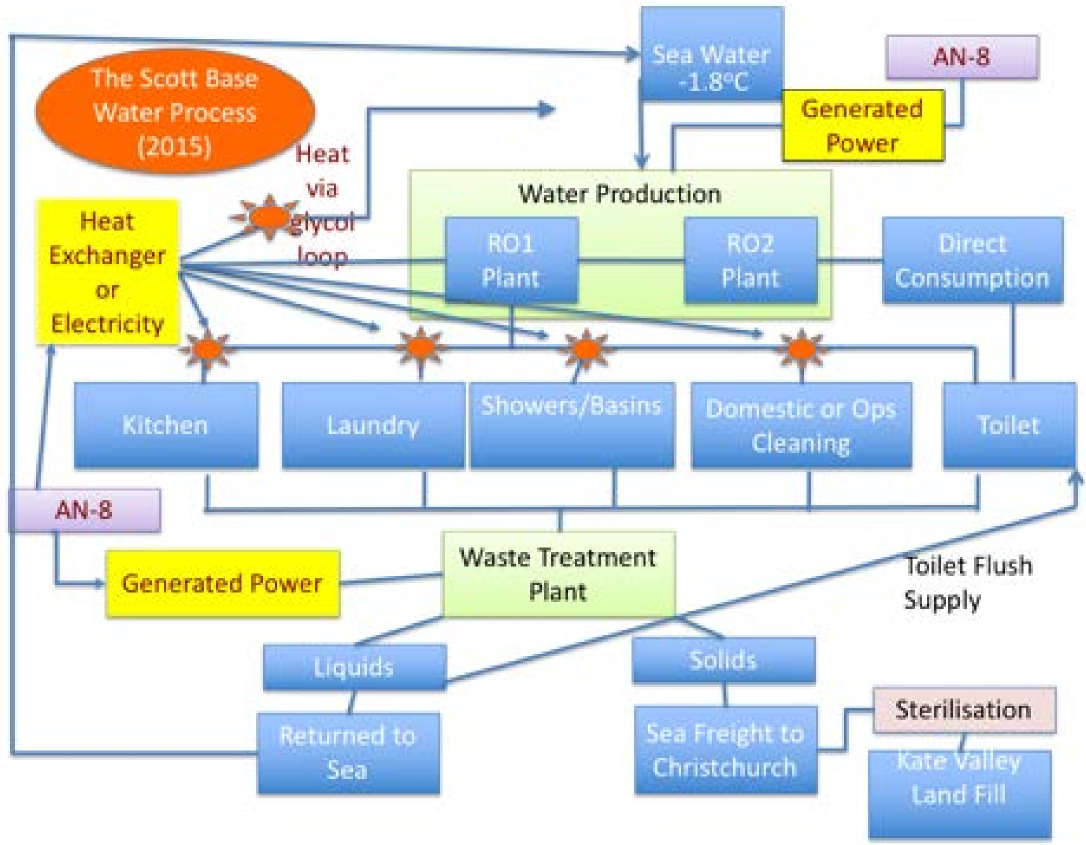


Fig 5. The Scott Base Water Process

2. Electricity – with the exception of the more modern bases, electricity is produced using fuel powered generators, however, solar and wind generated production is becoming more common. As Antarctica is a windy climate, wind generation can be achieved 12 months of the year, however, the long Antarctic winter 'night' means that solar production is not continually available for continually inhabited bases. Summer only bases have quite different limitations.
3. Waste – Due to the ATS requirements, all waste, must be removed from Antarctica. The cost of appropriate waste handling in Antarctica is large, as the waste is typically returned to the base's operating country for processing. There, depending upon the import restrictions, it may have to be treated prior to it being processed as rubbish. Waste is another human interface, where our habits can significantly impact the amount and tripe of waste that needs processing.
4. Heating –For hygiene, health and safety and comfort reasons, the inside temperature needs to be regulated, despite the outside air temperature range at Scott Base getting as high as a few degrees above zero to a record of -57°C (25 September 1968) and an average temperature of -20 °C. (Source: NIWA 2015), the inside air temperature is a manageable variable.

   The better insulated a building is, the more heat remains trapped in the building rather than escaping into the environment in the form of infrared radiation. This means less energy input is required in order to maintain a consistent inside temperature. Energy for heating varies, not by the number of people on base, but the inside/outside temperature differential.

As the base has been constructed with heat lock type doors, with the exception of the large vehicle doors on the workshops, the insulation of the building sets an inflexible constraint, as there is little that people's habits can do that will impact the energy requirements for heating.

5. Transportation – currently, ALL transportation is fossil fuel dependant, and, due to the low temperatures (with a brief expectation to the warmer weeks of summer), solutions involving battery storage become impractical and unreliable as the performance seriously decreases below -10 °C for most current battery technology. As there are no/few technological alternatives currently available, the only gains to be had in transportation come from effective vehicle scheduling, more fuel-efficient vehicles and lower volumes.

All of these activities have a heavy reliance upon burning fossil fuels for energy (although not exclusively), which is illustrated below:

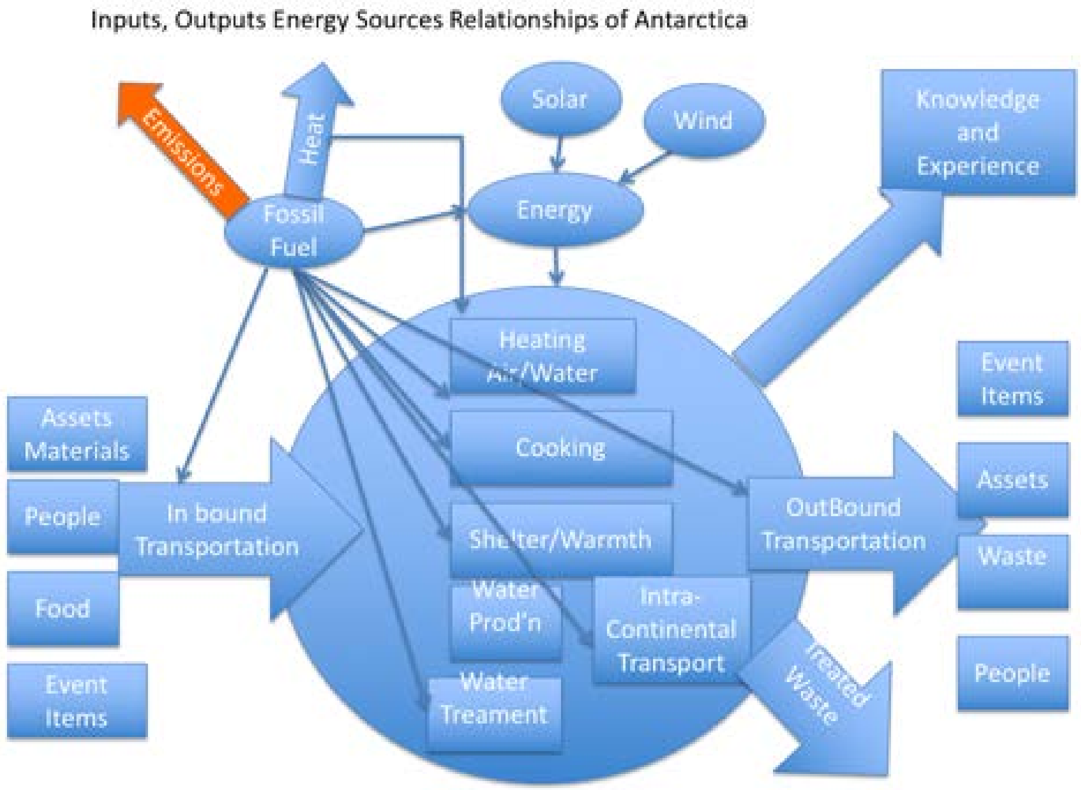


Fig 6. Map of Fossil Fuel Dependence

Fossil Fuel as a Source of Energy

There is currently no readily year round, readily available, reliable, and environmentally clean source of power in Antarctica. The Antarctic diurnal pattern (day long sun in summer and night long darkness in winter) means solar power is seasonally limited as well as weather influenced. There is not a common availability of geothermal power and wind generation is weather dependent.

While Nuclear power is not explicitly not allowed within the environmental restrictions of the ATS, nuclear weapons and nuclear waste dumping is. In what turned into a costly experiment, the US Navy operated a nuclear power plant near McMurdo Station from March 4 1961.

During the approximate 10 years of operations the nuclear power station produced over 78 million kilowatt hours of electricity and produced 13 million gallons of fresh water using excess steam fed to a desalination plant, which reduced the consumption of fuel. However, as it required 23 personnel to operate and offered only 72 percent availability, it also required a diesel power plant to be staffed year-round as backup.
On going maintenance and repair costs also proved substantially more expensive than expected. The plant suffered 438 documented malfunctions at the plant from 1964 through 1972. Finally, the discovery of a leak from the coolant leak sealed its fate in 1972 (amongst prohibitive associated repair costs). The plant was decommissioned and dismantled during the late 1970s, taking 7½ years, including the removal of about 9,000m3 of radioactive dirt from the site to a disposal site in in California (via Lyttelton, New Zealand) in order to comply with the Antarctic Treaty non-dumping obligations.
During operation, 223 reports of abnormal levels of radiation were recorded in drinking water and environmental contamination, and several recorded instances of crew radiation exposure, some resulting in injury.
In 2013 in the US, a federal hearing explored whether radiation exposure contributed towards cancer in ex-Navy veterans.
(Sources:News Network 5 2015, Antarctic Sun 2015, A Green Road 2015)
The high reliance of Antarctic operations and the connected emissions can be illustrated in the following chart of emissions from Antarctic NZ operations.

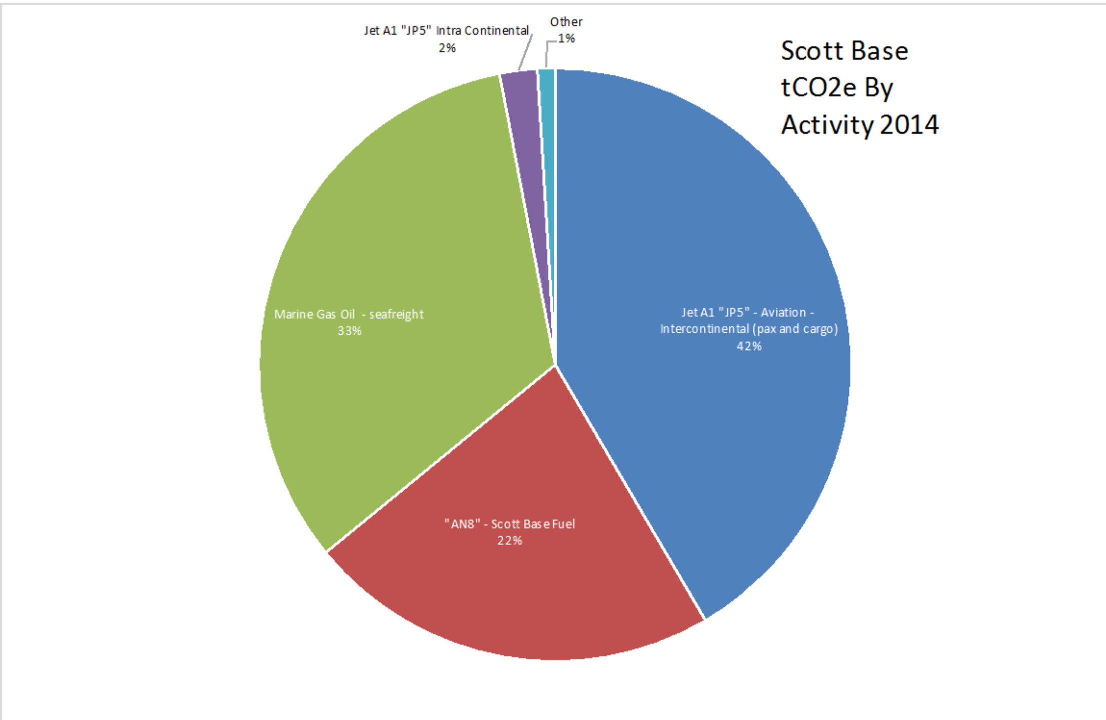
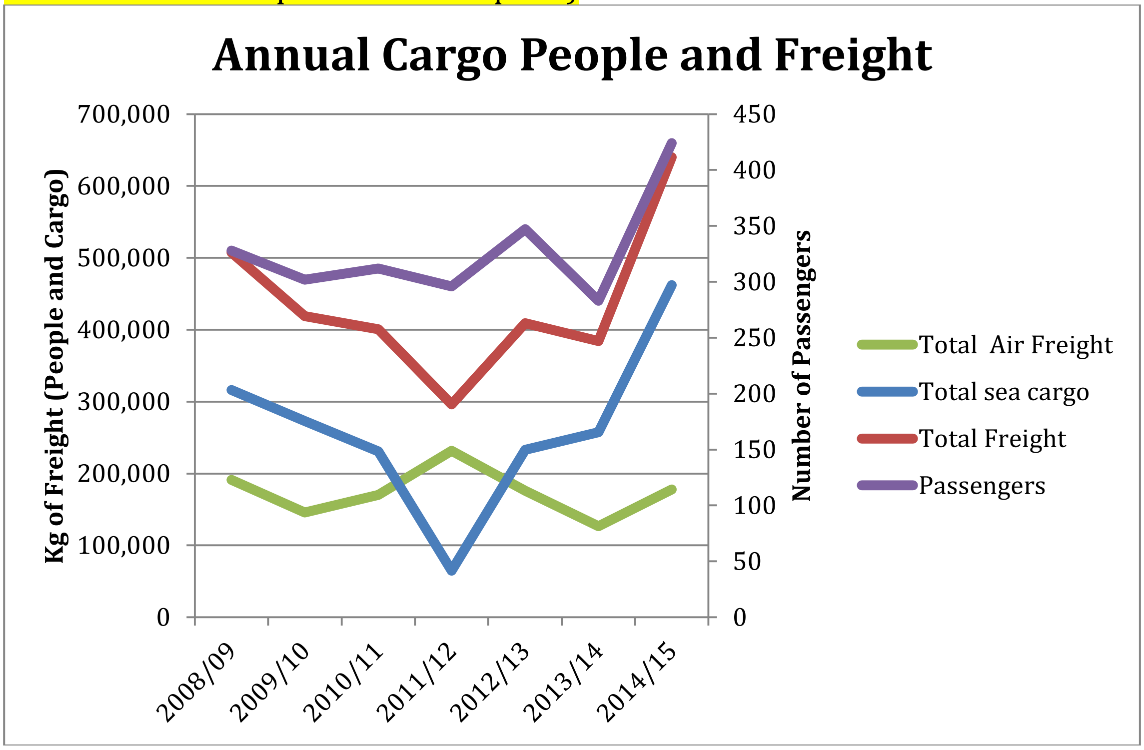


Fig 7. Scott Base CO_2 Equilivent Emissions By Activity in 2014
Total emissions are highly dependent upon the activities in any given year. In the 2015 winter season, the HFC required construction materials that pushed the normal volume of freight transported south by both sea and air (people and cargo), forcing a corresponding increase in tCO2e as shown in Fig 7 with air and freight being the source of 75 percent of the emission which were above normal due to the level of activity.
Compounding the challenges of managing emissions related to freight, the vessels and aircraft are all operated by 3rd party contractors (US Dept. of Defense, NZ Defense etc.) and, with the expect of the quantity of freight and people travelling, the management of

efficiencies are largely outside of Antarctica NZ control (referred to as Scope 3 Emissions – add scope 1 and 2 desription)



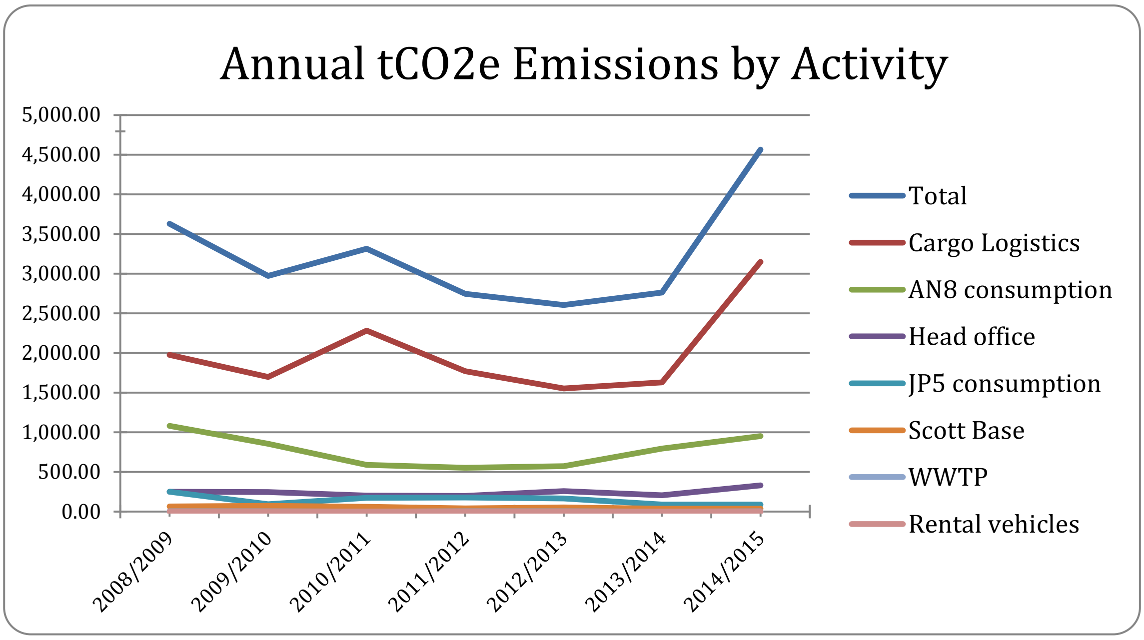


Fig 8. Volume of Cargo (People and Freight) from 2008/9 to 2014/15

Fig 9. Emissions by Activity 2008/9 to 2014/15

Selection of Comparative Denominator

While the total level of usage is of interest for budgeting and environmental purposes, the use of an appropriate common denominator allows comparison between years (to determine initiative success and to predict future base requirements as well as possible comparison to other bases). In most instances the number of inhabitants is an effective denominator (i.e. units of resource per bed night during a period) as it is the key variable that impacts the amount of resource required. For aspects such as the fuel required for heating, the key determinant is not the number of people on base, but the difference between the inside and the outside temperatures, which is seasonal. Careful consideration is required when deciding upon a comparative denominator as patterns can coincide. The graph of occupancy and heating fuel (fig 10) use looks inversely related, (less fuel is required as the number of people on base increases) however, this is incidental, as people turn up during the summer, when less heating fuel is required. Being able to isolate normal base activities from strategic activities (such as building) becomes important if assessment of overall emission reduction programs is to be accomplished. For this reason, bulk of the following uses the number of bed nights in a year (or month) to obtain a comparative figure. Largely, the numbers available were for daily figures from the Building Management System (BMS) or annual summary figures.

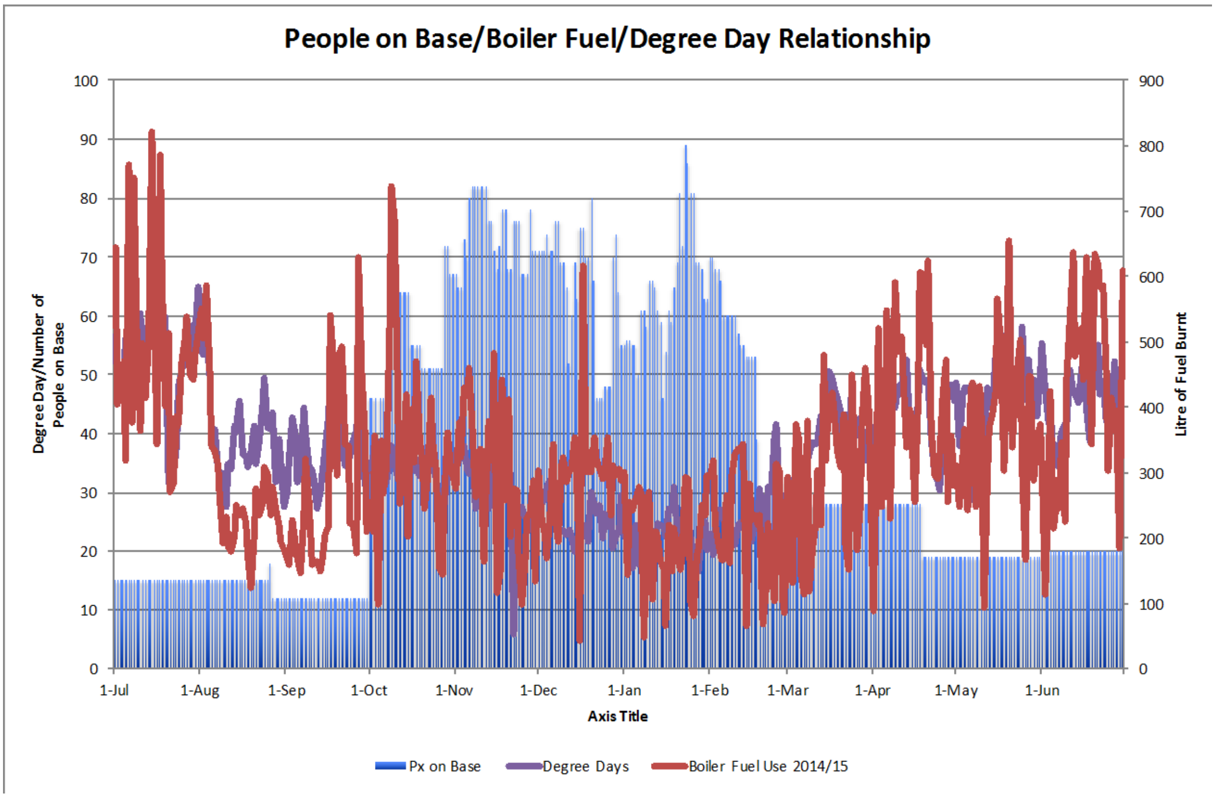


Fig 10. People on Base/Boiler Fuel/Degree Day Relationship

3 Results/Discussion

It became very apparent, very quickly that, despite being a small base, there is much activity variation and that no year is directly comparable to any other. Just the number of people on base a year makes direct comparison of total consumption levels irrelevant. Add to this innovation such as the creation of the Wind Farm and the RIEG with McMurdo controlling the Scott Base generator operations, things become very confused.

Occupancy Variation

This section is broken into 2 parts, production of resource, and consumption of resource.
The level of occupants can be seen in the table below

Season	Person Days	Average People Per Night
2009/10	12705	35
2010/11	11042	30
2011/12	10754	29
2012/13	11823	32
2013/14	10835	30
2014/15	13374	37

Fig 11. Table of Occupants (Annually and Per Night Average)

In the period 2009/10 to 2014/15, there has been an average of 11,756 bed-night occupancy at Scott Base, and a maximum of 13,374 in 2014/15. With a difference of over 1600 nights between the average and the maximum, comparing year on year figures becomes meaningless as this skews the total fuel and resource consumption upwards. With the exception of heating, the occupancy rate has been deemed the most suitable denominator in order to create comparable figures.

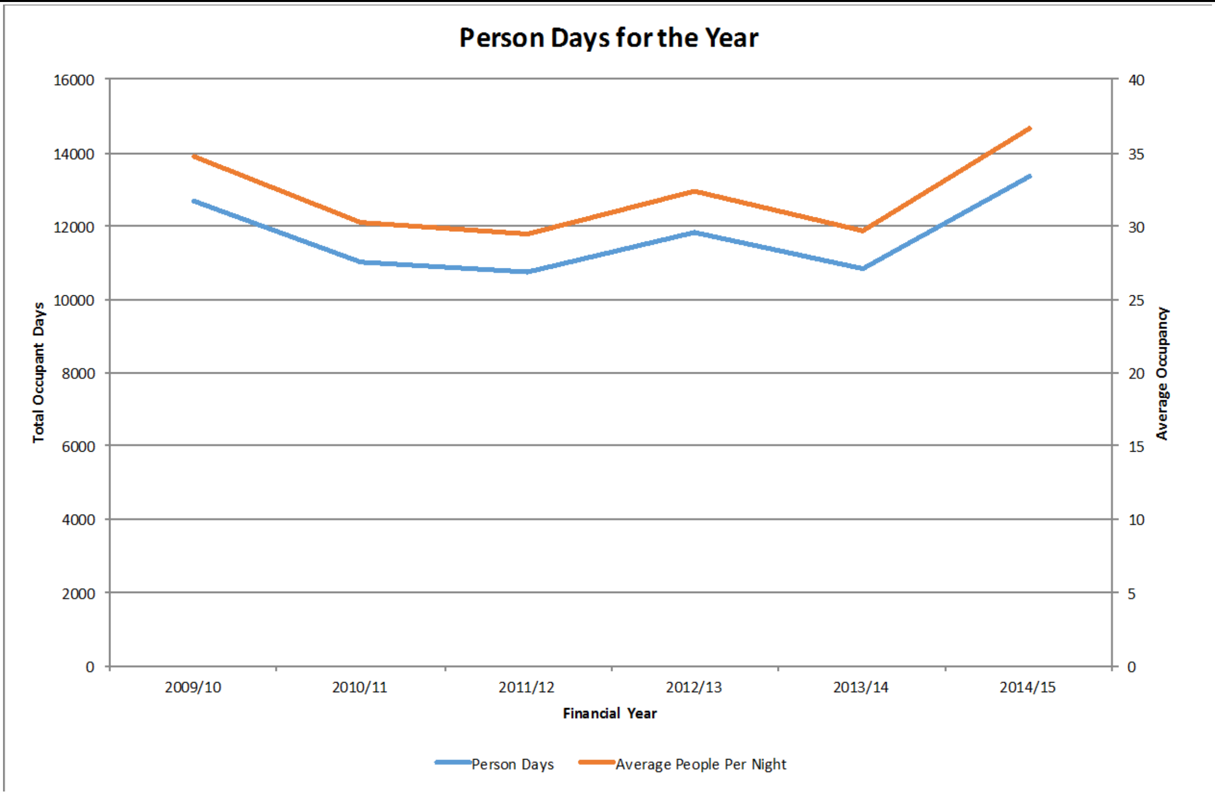


Fig 12 Total and Averge Number of People on Base

The seasonality of the activity centred around Scott Base changes dramatically by season, with a much reduced population in the winter, and a heighted population during the summer as the science data collection season starts. Much of the increase in 2014/2015 could be attributed to the construction crew completing the HFC refurbishment during the winter. Variables such as the HFC refurbishment distort the level of resource use, but a reliable common denominator (such as the resource use per person makes the years comparable.

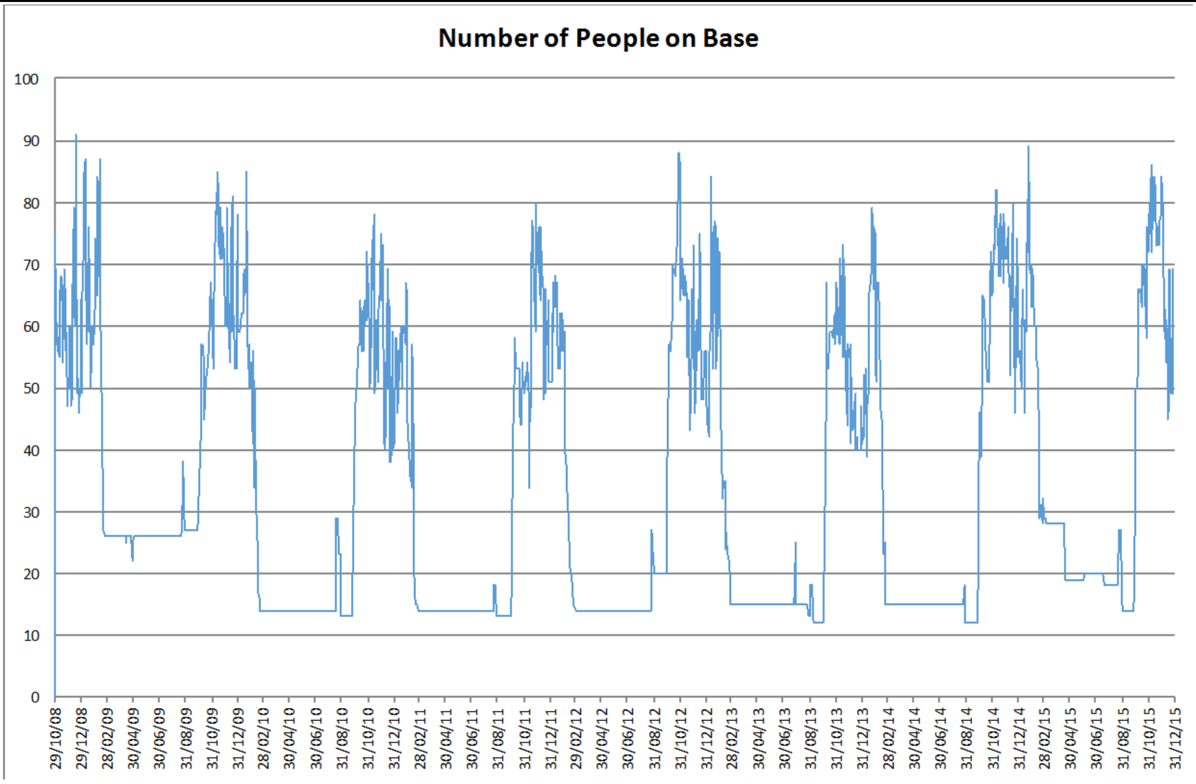


Fig 13 People on Base – 2008 to 2015

Resource Production

Production – Wind Farm

Both the financial savings and reduction of total CO_2 equivalent emissions (tCO_2e) of the energy produced by the Wind Farm contributes to the Ross Island Energy Grid can be measured, and is considered to be a part of the Antarctica NZ contribution in the shared logistics program with the United States Antarctic Program (USAP). All fuel savings have been calculated using a price of NZ$ 2 per litre for AN-8 and 2.54kg of tCO_2e embedded in each litre of AN-8 consumed.

Savings From Wind Farm Generation 2014/15	
Wind Farm Production (kWh)	2,331,895
Litres of AN-8 / kWh	0.28
Litres of AN-8 Saved	654,968
Price Per Litre	$2
$NZ Value of Fuel	**$1,309,936**
tCO_2e kg/l AN-8	2.54
tCO_2e reduction (tonnes)	**1,663.6**

Fig 14. Savings from Wind Farm Generation

The Scott Base Consumption of electricity for 2014/15 was 961,497kWh, meaning that, in terms of Scott Base operations (i.e. excluding Christchurch head office and logistics), about 2.4 times as much power was generated as was consumed, the fuel that would have been burnt producing the difference (1,370,398 kWh), reducing emission production by 1,559 tonnes with an associated cost of $1,227,644 (note, this is over simplified as it excludes maintenance and associated costs and does not account for establishment costs of over $12m and an unknown investment in carbon emissions in order to establish the Wind Farm). This reduction can be considered a carbon credit, to off-set against other emission sources (See Summary Table Fig 16).

Production – RIEG Generator Automation

In order for the Wind Farm to be of a viable scale, the energy requirements of both McMurdo Station and Scott Base were combined – creating the Ross Island Energy Grid as a shared network between the stations. Recently, the USAP took over the running of the generators at Scott Base in order to optimise AN-8 powered generation of electricity for RIEG. McMurdo Station has 5 large (1200+ kWh generators), while Scott Base has 3 smaller (180kWh) generators. Each generator size has a level at which it is more efficient at producing electricity for each litre of fuel burnt. The inclusion and automation of the Scott Base generators allows the network generators to be optimised. Using publically available generator efficiency data (see Appendix), a possible scenario has been built up assuming optimised running of 2 hours per day. This scenario is illustrative only, and could be substantially improved with actual figures.

Estimated Fuel Savings By Optimizing Generator Operation		
	US. Gal	Litres
Fuel Savings/Hr.	8	28.4
If Optimised for	2	hrs/day
for	365	days per year
Reducing AN-8 burn	20750	Litres / year
Assuming AN-8	$2.00	/Litre Landed
Total Savings	$41,501	/ year
Reducing tCO2e	53	tonne of emission

Fig 15. Generator Optimisation Savings Estimate

Production Savings Summary

Summary of Production Side Initiatives

Production Savings of these 2 initiatives can be summarised as:

Production Side Savings					
Wind Generation	Financial Savings at $2/l		$1,227,644	NZ
	tCO2e Savings		1,559	tonne
Generator Optimisation	Financial Savings at $2/l		$41,501	
	tCO2e Savings		53	tonne
Total Production Cost Savings			$1,269,144	
Total Emissions Savings			1612	tonne
2014 Scott Base AN-8 Related Emissions	953	tonnes or	169%	of 2014 Levels
2014 Total Emissions	4,229	tonnes or	38%	of 2014 Levels
Comparison to 2014 Usage in order to show degree of relative savings only				

Fig 16. Summary of Production Side Savings

How ever, this does not account for Wind Farm investment either financial (approx. $12M in 2008) or emissions costs (unknown) that would be required in order to determine an actual authentic return on investment in either form (a recommended activity that would hold value especially for bases considering refurbishment of their electrical production facilities).

Resource Consumption/Demand

Water

While consumption levels going back to (and prior to) 2008 were not available at the time, pre-2008 water consumption is supposed to have been in excess of 150 litres per person per day. Of all of the resources required (i.e. excluding transport) water is the costliest due to the numerous stages involved in the water cycle.
In 2008, as a result of a final year project called Sustainable Energy on the Ice, a Sustainable Energy Protocol Package that included creating an awareness as to the cost of resources or activities (e.g. one load of washing costing $21, requiring over 6 litres of fuel and contributing to 5% of Scott Bases fuel consumption. The idea of 'Take your last laundry home!!" was also started. Even today, a part of the weekly base meetings is a report on the level of per person, per day water consumption that has occurred for the week.

Estimated Annual Water Savings vs 2008		
Water Use	2008	2014/15
(Litres/Day/ Person)	150	102.5
Reduction		47.5
AN-8/litre Water		0.049
Savings Per Bed Night		
Fuel (litres)		2.3
tCO2e (kg)		5.9
2015 Occupancy		13374
Annual Savings at 2105 Occupancy		
Fuel Savings		31,128
at	$2	$62,256
tCO2e (kg)		79,065

Fig 17. Estimated Water Savings 2015 vs 2008

Power Consumption

If the measure of total power consumed over the year were to be taken as the management measure, it would be misleading. In 2014/15, the total power consumption was up on the previous year, but so was the number of people on base over the year, actually giving a resulting decrease in the power consumed per person.

(Note that in the fig 19, Annual kWh per person has been multiplied by 10 in order for it to show up on the chart, and to show the changes relative to the other 2 variables.

There will be 2 key factors at play in variation of the per person per day power consumption. The first will be the division of non-variable demands and non people related (ie Waste Water Treatment and heating) which, when there are more people on base will give a lower per person contribution. The other is seasonal or activity related ie event personal preparing or de-mobbing for field events.

It is interesting to note that the level of power consumption per person has dropped in 2014/15. This aspect has not been looked into. It would be interesting to compare pre-2008 power consumption to the data available in relation to reduction related to the SEPP initiative.

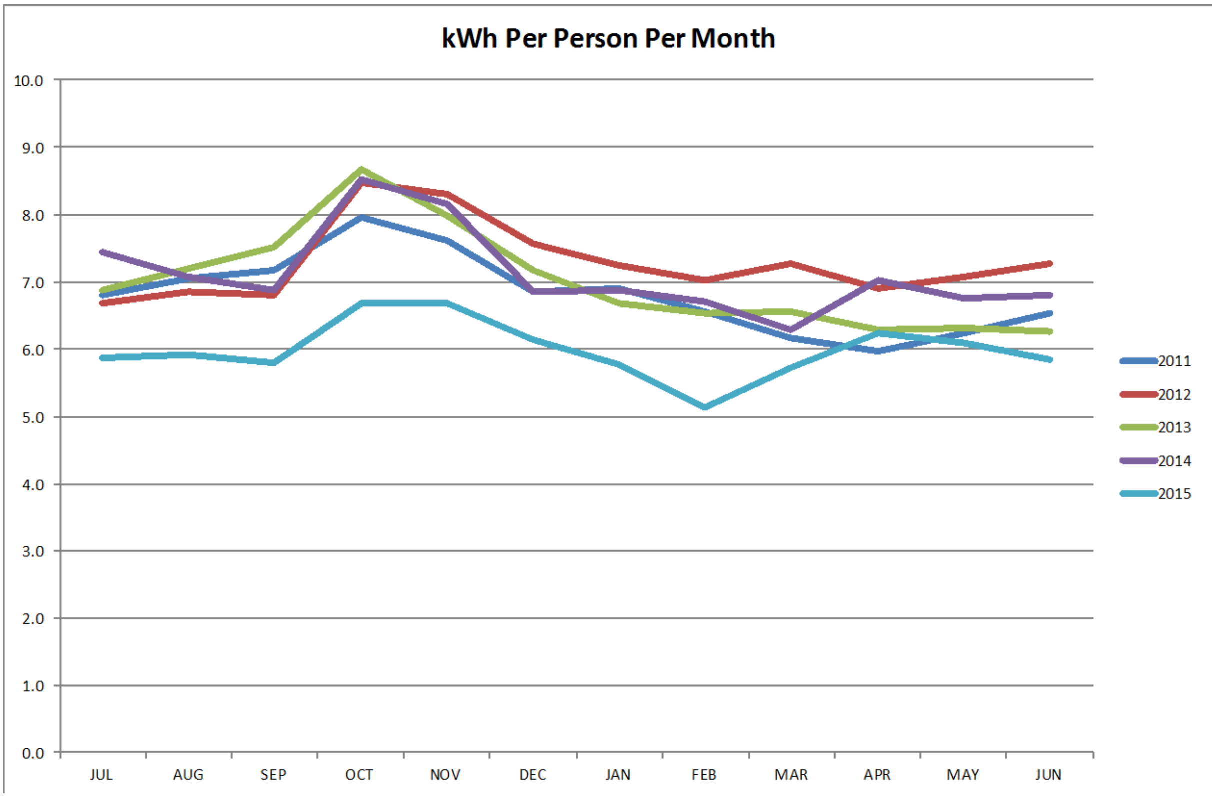


Fig 18 Power Demand per Person per Month 2014/15

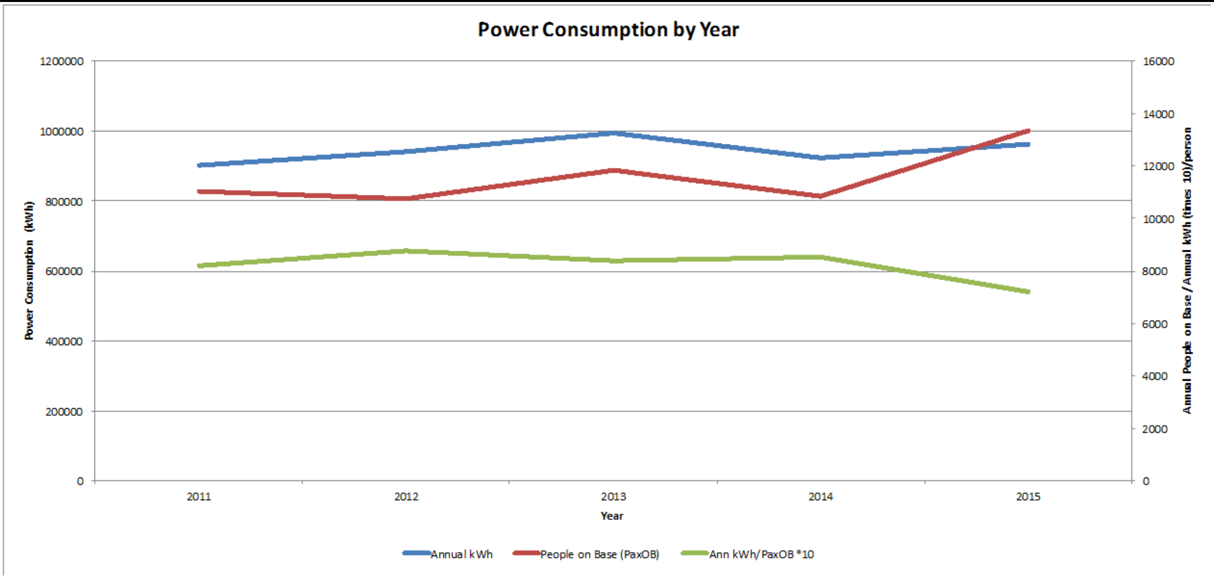


Fig 19 Power Consumption per Year 2008-2015

Waste

The benefits of managing waste include reduced transportation costs to Scott Base, reduced handling at Scott Base, reduced return transportation of waste back to Christchurch, and reduced disposal costs in Christchurch.

Over the years, both the management and the culture around waste has changed, focusing on reducing excessive packaging prior to southbound departure, and where possible, de-selecting consumption items that have high waste attached (such as corn on the cob). While the removal of excessive packaging exports the waste issue to Christchurch, it reduces the Antarctic related transportation costs and sorting activities. Culturally, although the food is served up as self help/smorgasbord, the culture has been shifted away from a "take what you want, eat what you like and throw the rest out" approach, the request is to "take small portions, you can always go back for seconds" behaviour. Additionally, the chefs (mostly!) appropriate reuse left over's helps to reduce the level of waste and associated costs.

The benefits of of food associated waste reduction are multiple. It reduces the amount of food that needs to be transported south, the waste that needs to be transported north, and the amount of waste that needs to be sterilised and transported to landfill once back in Christchurch.

In fig 20 Waste Per Year 2008 -15, it is worth noting that, despite the increased occupancy, the total volume of food and human related waste has decreased (although the dip in 2010/11 is difficult to explain!)

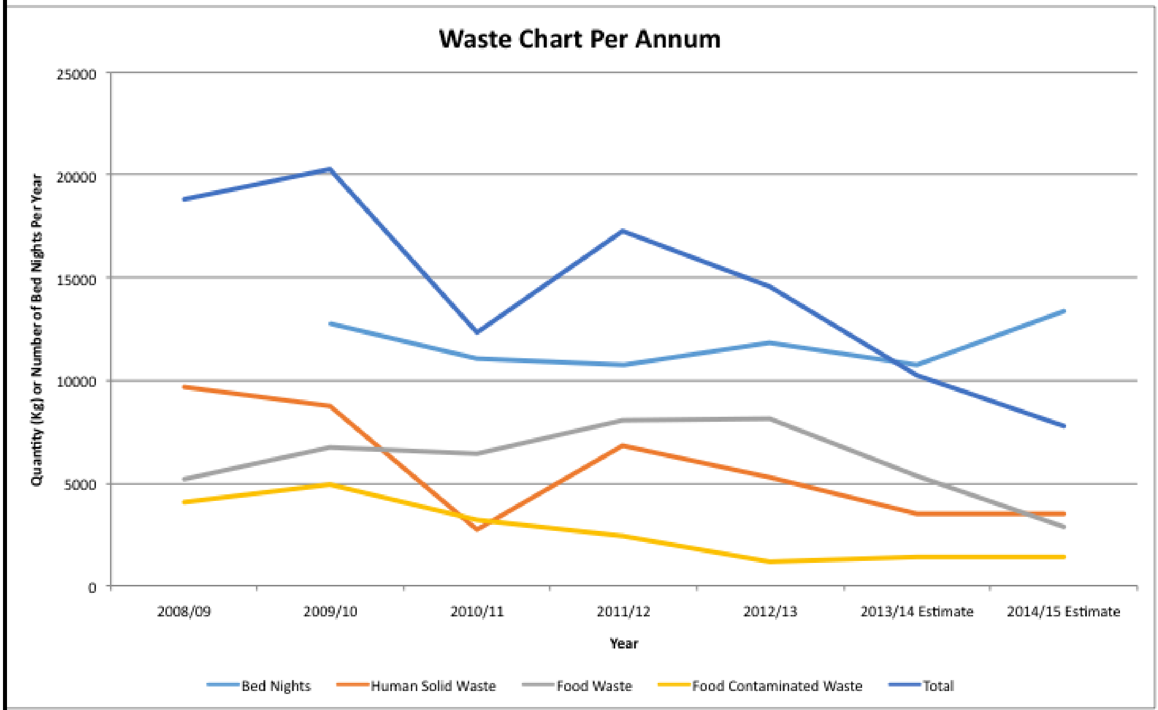


Fig 20

Waste Per Year 2008 -15

Heating

Heating is an aspect that does not vary by occupancy levels, but rather by the inside/outside temperature differential (measured in degree days – i.e. the differential on a particular day). While it may appear that fuel requirements decrease as occupancy increases (a somewhat illogical conclusion), this is simply because people turn up for summer activities as the temperature differential decreases over the summer. As in Fig 21 "Inside/Outside Temperature Differential (Degree Days) vs Boiler Fuel Use", the fuel requirements and temperature difference are tightly linked – the greater the temperature difference, the more fuel is required.

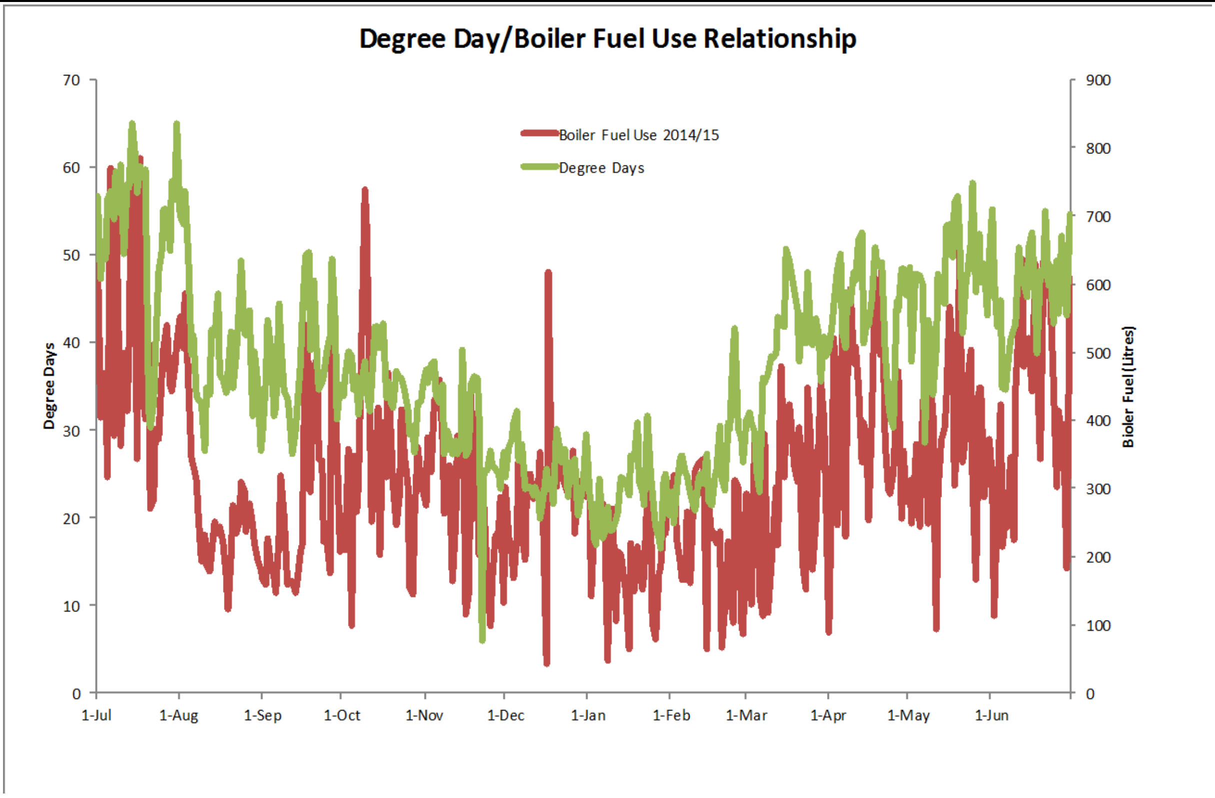


Fig 21 Inside/Outside Temperature Differential (Degree Days) vs Boiler Fuel Use.

During the PCAS 2015/16 visit, the temperature was noticeably warm inside. Despite the outside temperature, it was common to see people wearing t-shirts. The inside temperature is a manageable variable, for which the energy can be calculated for every degree of temperature difference.

Estimation of Annual Heating Fuel Requirements per Degree of Inside/Outside Temperature Differential		
2014/15 Boiler Fuel Burn	117,668	Litres
Total Degree Days	13,584	Degrees
Avg. Litres Fuel /Degree/Day	8.66	Litres
	3,162	Litres Per Year
	$2	AN-8 Price
	$6,323	$ Per Year/ degree
	8,030.62	tCO2e kg per year / degree
	8.03	tCO2e tonnes per year / degree

Fig 22 Estimated Possible Heating Savings

If the inside temperature were to be reduced 2 degrees, little change in comfort would arise (other than possibly having to wear an additional layer). Savings in doing so can be estimated as below.

Estimate of Savings With 2 Degree Temp Reduction	
2	Possible Inside degree reduction
12,647	Total $ Savings
16	Total tCO2e Tonne Savings

Transport

Air transport is the greatest single generator of cost and emissions for NAPs.
For Antarctica NZ, transport is provided by 3rd parties, and as such data was not readily accessible. Relative to the rest of the base operations, even a small improvement in transportation costs will be significant, but due to the nature of logistics and the associated constraints, improvements will be hard won.

The most obvious place gains can be made is simply by having less people and cargo travelling. How volumes are determined is well outside of the scope of this report, and the inclusion of the programs or events that get supported is a considered process (possibly outside of Antarctica NZ's determination), while the levels of staff and management is determined by Antarctica NZ, this is also outside of scope.

The link between average fuel use per kilogram rises significantly when non-jets are used for inter-continental travel, particularly when LC-130 ski Hercules are used outside of the season for ice runway at Pegasus Airfield.

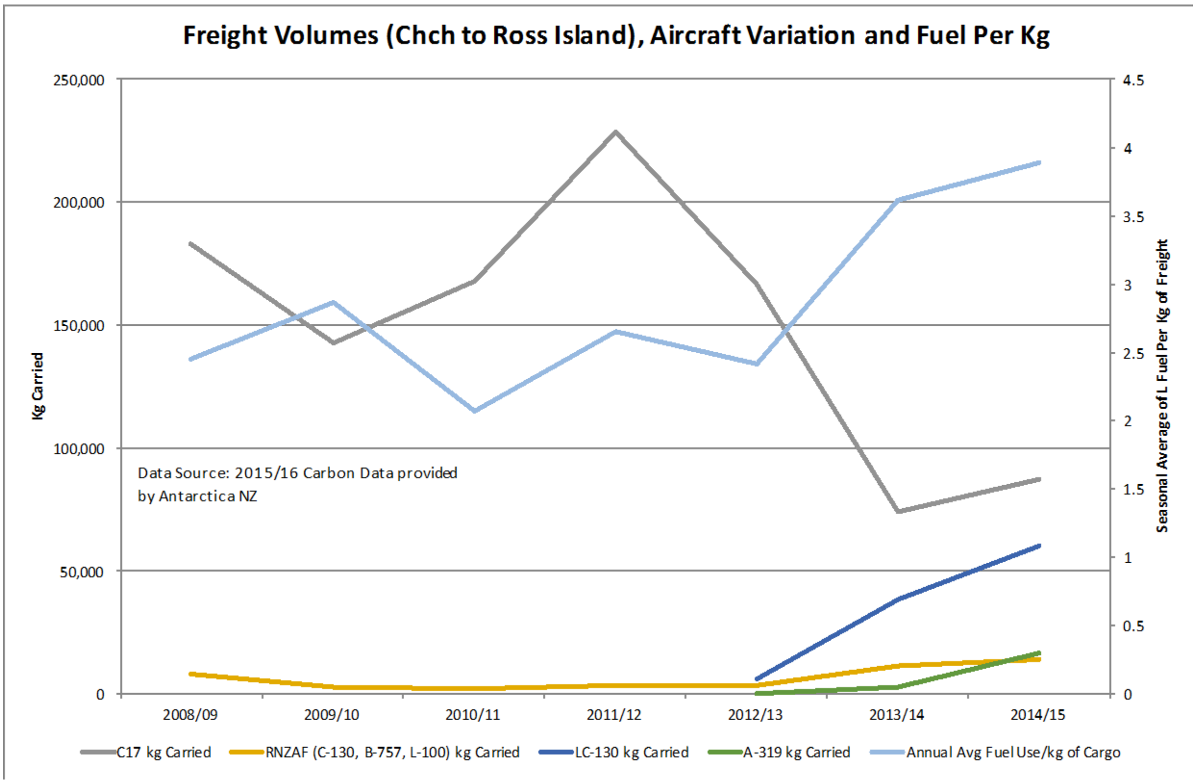


Fig 23 Chart of Freight Volumes, Aircraft and Fuel Use

As illustrated in Fig 23 Chart of Freight Volumes, Aircraft and Fuel Use, season length has a big determinant on the fuel burnt, travel cost and emission production. If short seasons become the norm, (which seems probable due to safety concerns of using Pegasus Airfield) it may become prudent investigate alternative travel strategies (no current suggestions however!).

Summary of Demand Side Savings

Although each of the results from demand side management initiatives my not look significant, their return on investment is substantial, considering no expensive infrastructure changes have been made. Combined, the initiatives add up as summarised in Fig 24 Table Summarising Demand Side Savings.

		Year of Comparative Da									Per Bed Night Savings	
Area		2008	2010	2011	2015	Reduction	AN_8 per L/Unit	Savings Per Bed Night	$/Unit	(Kg) tCO2e per Litre AN-8	$ Savings	tCO2e Savings (Kg
Power	kWh/ bed-night			81.8	71.9	10	0.174	1.73	$ 2	2.54	$ 3.46	4.40
Water	Litres/bed night	150			102.5	48	0.049	2.33	$ 2	2.54	$ 4.66	5.91
Waste (Freight)	kg/bed-night		1.60		0.6	1.0	1.2	1.22	$ 2	2.54	$ 2.44	3.10
Waste (Sterilisation)	$/bed-night		$ 1.55		$ 1.11	$ 0.44		$ 0.44			$ 0.44	
											$ 10.99	13.40
								Bed Nights in 2015			13,374	13,374
								Est. Annual Savings			$ 146,990	179,246
								tCO2e Savings Tonne				179.25
								2015 tCO2e from AN-8				953
								Reduced Consumption as % of 2015				19%
	Potential Savings From Reducing Inside Temperature by 2 degrees								$ Per Year		$ 13,253	
	(Currently approx 20?) (see workings below)									tCO2e Tonne Savings		16.83
						Total (Historic Plus Potential Heat Savings)					$ 160,243	
												196.08
						Total Reduced tCO2e as % of 2015 Levels						21%

Fig 24 Table Summarising Demand Side Savings

If a 2-degree heat reduction were in place, an annual savings of $160,243 per year would be achieved, with an associated reduction of tCO2e of 21% over 2015 levels. Combining the demand side and production side together, Antarctica NZ has achieved cost and emission reduction as follows:

	Fuel Savings (L)	Emission Reduction tCO2e (tonne)
Production	**$1,269,144**	**1,612**
Consumption	**$160,243**	**196**
Total	**$1,429,387**	**1,808**

Fig 25 Table Summarising Overall Savings

Fuel Price Impact

Given the volatility of the price of fuel, a price table for each unit has been constructed (Fig 26) using the fuel volumes calculated by the 2008 SEPP.

At the time of writing the price of U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB was $1.08 per US Gal (0.42NZ $/L), over the last 15 years, the lowest price ranged from $.52 – 3.89 USD/Gal (0.32-1.35 NZ$/L) with an average of $1.94 USD/Gal (0.72 NZD/L), the cost of energy is very volatile and currently below average. Additional to the variability to fuel prices, the US/NZ exchange rate adds additional volatility.

Table of Resource Costs For Fuel Price Fluctuations												
				Price of AN-8 NZ$/Litre								
Item	Fuel Requirement (mL)	Capital Cost	Chch Equilivent Per Unit *	$1.80	$2.00	$2.20	$2.40	$2.60	$2.80	$3.00	$3.20
kWh Electricity	174	$0.41	$0.27	$0.72	$0.76	$0.79	$0.83	$0.86	$0.90	$0.93	$0.97
kWh Heat	135	$0.27		$0.51	$0.54	$0.57	$0.59	$0.62	$0.65	$0.68	$0.70
1 L Water	49	$0.08	$0.0013	$0.17	$0.18	$0.19	$0.20	$0.21	$0.22	$0.23	$0.24
Shower Per Minute	260.7	$0.41	$0.04	$0.88	$0.93	$0.98	$1.03	$1.08	$1.14	$1.19	$1.24
10 Min Shower	2607	$4.06	$0.38	$8.75	$9.27	$9.80	$10.32	$10.84	$11.36	$11.88	$12.40
Washing Load	4300	$7.93	$0.18	$15.67	$16.53	$17.39	$18.25	$19.11	$19.97	$20.83	$21.69
Dryer Load	1808	$1.72	$1.08	$4.97	$5.34	$5.70	$6.06	$6.42	$6.78	$7.14	$7.51

Notes

* Chch Electrical Cost is the Meridian Anytime Rate per kWh on 1 Feb 2015

- The capital costs in yellow seem high and need to be verified. Also, The washing machines and dryers have been replaced with more efficient machines, and these capital cost figures need updating.
- Chch Equilivant Rates were calculated using 2015 CCC Ratable information

Fig 26 Table of Resource Costs Based on AN-8 Price Variation

U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB
Jan 2001 - Dec 2015

	USD/Gal	NZD/L
Min	$0.52	$0.33
Max	$3.89	$1.36
Average(	$1.94	$0.72
Current	$1.08	$0.42

Source : http://www.indexmundi.com/commodities/?commodity=jet-fuel&months=180&currency=nzd

Fig 27 Table Showing 14 Year Jet Fuel Price Statistics

Cultural Shift and Demand Side Management – How it Works.

Culture shift works in the basic need of human beings to feel accepted and valued by the community. Essentially, we care what others think of us, and it feels good to be regarded as doing the “right thing”. It is at its strongest when it becomes “because it is what WE do” and it becomes a part of our identity (who we see ourselves as being).

To go to a community and ask them to change their habits in order to consume 1/3 less, all sorts of resistance and objections will be raised because we are being asked to change. However, by adopting an information and awareness approach such as established with the SEPP, you can actually provide a way for people to feel good by changing and progress becomes achievable. The nature of occupant turn-over (both visitors and base staff turn over) plays well into this, as it is easier to have new arrivals start in the desired way, rather than changing long established habits.

The Scott Base initiates this process well, as experienced in our base orientation in December of 2015.

The recognised process for establishing Demand Side Management cultural shift is achieved by providing the context for participants, providing information that relates to their activities, specific targets are set (with associated impacts), participants tend to want to participate (in order to be well regarded), which forms the group behaviour that maintained with ongoing feedback and reinforcement.

It is a System.

The innovative and resource aware engineering team are aware of the delicate inter-relationship of the base systems.

While not estimated in this report, one example of inter-relationship is the lighting, where, while very energy efficient LED lighting is available, the decision has to NOT install it at this point, as LED emits light very efficiently – but without the heat that current T5 style lighting has. If the lighting were to be switched over to LED, it is known that additional boiler fuel burn for heating would occur. Together with the transportation costs, salaries, waste removal, T5 fitting disposal and miscellaneous costs etc., reducing the effectiveness of the initiative. In as remote a location as Scott Base, this level of consideration is important, and one that the staff are mindful of. (A similar situation can be found with the BMS, which, by the time it was researched, purchased, installed, plus on going management and maintenance - including annual calibration of numerous sensors, the actual net return can become eroded. The exercise of <u>estimating</u> the actual net return would be possible but complicated – it may highlight some interesting lessons for future initiatives).

Culture

In the 2008 the Sustainability Energy Protocol Package (SEPP), suggested that automated shower timers be installed, where, after a set period of time, the level of hot water flow is reduced, slowly giving the shower an increasingly cooler temperature – encouraging shorter showers. These timers have not been installed, instead, at the base initiation, there is a conversation with newly arrived guests about water use and water conservation. At this point, a brief discussion occurs, bringing guests attention to the fact that the base needs to manufacture water (via the RO plant) prior to heating it and treating it appropriately prior to it being returned to the sea in a near pure state. At this point, guests are requested to keep their showers to approximately 3 minutes, and for similar reasons, to take their last load of washing home, at this reduces guest use of washing machines and dryers by about 20%. (Food Waste is another aspect that is communicated but could be improved)

One of the other tools used is regular up to date information regarding resource use. Scott Base runs a regular Friday 3pm meeting, that all staff and guests attend. One of the topics at this meeting is the level of water usage each day. For the first meeting that PCAS 2015 attended, the level was some 95 litres per person per day (led). The second meeting we attended it was at about 108 lpd. While the number will naturally fluctuate depending on the groups moving in and out of the field, what is important, is that the feedback installs a continual awareness in peoples thinking, and this awareness permeates into general awareness and culture. A number of personal conversations indicate that this <u>may</u> not always the case, and that substantial changes of been achieved over time).

While not having experienced an induction at McMurdo Station, just a brief visit to McMurdo shows the culture to be very different. During a tour of USAP's very impressive water treatment plant we were told that McMurdo expects to go through 120-130 US gallons per person per day (454-492 litres) – approximately 4.5 – 5 times the water as Scott Base. Although McMurdo is a very different base to Scott Base (with the Department of Defence providing the joint air logistics, a much more developed Crary Science Laboratory and able to accommodate 1258 residents (vs Scott Bases' 85) (Source www.wikipedia) 450 litres of water lpd is very substantial difference. (450 lpd

for the base is 600,000l of water per day at full capacity – just under a ¼ of an Olympic swimming pool at 2,500,000 L)).
This aspect of cultural initiatives and differences is an area that I believe would give the joint NAPs a substantial return. Again, using McMurdo as an example, if the culture can be correctly managed so that water use was reduced from 450lpd down to 200lpd (251,000 litres for the base per day) the cost of water production would be close to 40%. It is essential to remember that, in its current form, McMurdo will have systemic minimums it needs to meet and any approach must be balanced to this. However, as McMurdo is gearing up for a major renovation, if the culture around resource use were to be treated as a transitional stage PRIOR to designing the new infrastructure, the savings in capital costs, installations costs, logistical costs and annual running costs (not to mention carbon footprint costs) must be worth carefully investigating.

Can Antarctica NZ Set the Bar Even Higher? - What is Possible?

Antarctica NZ is proactive in appropriate environmental management, however, now may be the time for an even higher level of activity.
In December 2015, amongst much fanfare, media attention and self-congratulation, the Inter-Governmental Panel on Climate Change announced that it was committed to limiting global warming to 1.5 °C. Since then the delegates have all climbed on jet planes and returned to their respective countries (ironically flying first class or business class) followed by a profound lack of plans of just how this bold goal is going to be reached. However, a lack of Inter-governmental plans does not stop us, as individuals, scientists, educators, managers and business owners by starting to take action today…but something IS stopping us. The IPCC recognised that 98% percent of scientist recognise that climate change IS happening and it IS caused by human activity (namely burning fossil fuels) …but I have yet to hear of anyone doing anything substantially different in the light of this awareness. This silence is even MORE concerning.
There is a field called Climate Change Psychology that recognises this awareness/action disjoint and has taken steps to explain it. Almost an extension to this report, a challenging underlying question seems to be: "For what we know, are we acting appropriately?"
Having had the privilege of brief experience of Scott Base and Antarctica, I believe that Antarctica is
Although outside of this report topic, the question "<u>Are we doing all that we can?</u>" is a challenging one, and one that leaders (and individuals) around the world need to come to terms with, and to answer with integrity. If we are not comfortable with the answer

In a presentation to the International Congress of Applied Psychology (2010), titled "Seven Dragons of Inaction – Why We Do Less Than We Should", Prof Robert Gifford builds the discussion about the human aspects that create the information to action disjoint.

Gifford describes 7 aspects of the human psyche that have influence:

1. Limited Cognitions.
   Namely that the changes that are occurring around us are very hard to perceive, not enough knowledge, too much conflict in information from science, and events that happen far away from us in location or time are discounted heavily, giving preference to immediate events.

2. Other people
   While the media has influence over us, our concerns of what other people think of us and how we compare to life-long social norms is more powerful. As activism and early adapters gain strength, peoples actions encourage us to follow suit.

3. Perceived Risks
   People tend to be risk adverse, and so decisions to embrace change tend to be difficult because of concern how the unknown factor may impact the outcomes of change.

4. Sunk Costs
   Prior actions, decisions and investments can make it difficult to change because the change may require us to give up what we have previously valued.

5. Ideology
   If a change requires us to act in away that our currently held view of the world would have us behave, further barriers to change exist as it may mean admitting that we were wrong about previously held convictions.

6. Distrust
   Our level of distrust (in a political structure, science, institution or even individual) we will be reluctant to go along with it

7. Limited Behaviour
   Our ability to see how our actions will make a difference comes into play here, as well as not being able to see options of how to respond because we have never done this before.

In “Don't Even Think About It - Why Our Brains Are Wired to Ignore Climate Change” George Marshall summarises by saying how it would be different if an external enemy existed, say, North Korea deciding to poke huge volumes of known pollutants into the air in order to destroy the global climate. The uniformity and level of our response would be very different. But this is not the case, there is no single external enemy to focus on, it is internal and it is all of us. Our ability to come to terms with this is the difference between whether we reach to the optimistic 1.5°C increase or pass it by.

The Funding Question

Science programs always have the issue of funding, and, as one of the key roles of Antarctica NZ is to support funding, the same issue arises. At a time when scientific research (particularly related to climate change) is needed, requests to support more field research which tends to be further from base, the current frozen budget is clearly not a viable match. (The Press Headline : “Antarctica NZ warns MPs - funding freeze cannot continue” February 18 2016)

A fixed funding structure does not match how Antarctica NZ operates. The chart of the number of people on base reflects both the activity levels as well as the constant and variable

demands of the base. The winter season shows the basic (relatively constant) base operating needs, and the summer season shows the additional requirements for field support operations, which changes from year to year, and seems likely to be expected to increase as illustrated in Fig . The other main variable, as discussed, is the price of AN-8. If Antarctica NZ is going to meet its objectives, the funding structure needs to reflect its operational structure. Crudely speaking, the model may look like this:
Annual Fund = (Base Budget + Field Support Budget) * Fuel Price Variable

Where the Base Budget is relatively constant (and arrives from central government), but the funds for the Field Support Budget arrives with notification of the approved science programs (add arrives from the approving agency – ie Ministry of Foreign Affairs and Trade). Naturally such a model would have its own issues (such as “how are we going to resource these programs” rather than “how are we going to finance supporting these programs)

Results/Discussion Summary

Future generations may look back and question our values. They may ask “For the level of awareness and knowledge we had, did you take appropriate action? Did you do all you could to mitigate the impact that the consumption of fossil fuels had on the future climate – the one we live in today?”

They will not care for the words or goals that were declared, or the health of the economy they inherited, but everyday, they will experience the state of the planet, created from man-kinds actions of the last 130 years, our action today, and our actions tomorrow.

Antarctica NZ has done well in reducing the financial and environmental costs of operating Scott Base and its achievements are noteworthy.

4 – Conclusions/Recommendations

In considering the conclusions and recommendations, it is imperative to remember that the Scott Base infrastructure systems is currently a balanced closed system, and, as such, no recommendation should be considered without further considering knock on effects to the remainder of the system.

The conclusions of this report are somewhat disjointed and could be greatly improved by compiling a clean data set to specifically and more accurately answer some of the aspects contained…particularly regarding resource use and the culture prior to 2008. Ultimately, I feel this area has much to offer Antarctica NZ, the wider NAP community, and even globally, as we come to terms with climate change and resource scarcity. Research into this field over a number of bases or NAP's would bear significant returns – however this creates a new chapter.

Despite a relatively short expose to the demands of running a continually occupied base on Ross Island, I hope the following suggestions are in line with what is achievable and practical:

Recommendations include:

- Considering the merit of a new funding model that matches Antarctica NZ Scott Base Activities.
- Developing a structured approach to using demand side management initiatives on base wide context.
- Identifying potential alternative uses for the energy currently via the heat dump doors.
- Consider reducing the inside temperature 1 -3 degrees.
- Using the PADS system to display to provide quality information regarding resource use (being care not to go over-board with this).
- This report contains a number of flow charts and information that could be developed to assist visitor awareness programs.
- Developing a video presentation that consistently and appropriately delivers this aspect during visitor orientation sessions, and pre-season staff training prior to departure for Scott Base.
- Development of alternative travel strategies (i.e. volumes, timing, flexi-flight etc.), particularly if jet travel continues to be restricted during summer months.
- Identifying resource loads may be deferred in order to reduce peak requirements – this may be a RIEG initiative.
- Identifying heat soaks (particularly during winter) and rectifying.
- Wider RIEG load patterns – load shifting
- Review all of system to identify priorities…design cultural shift mechanisms for each…starting with highest potential savings first …
- Better understanding on what DSM can mean to a system such as RIEG or Scott Base.
- Collaborate with USAP to get <u>actual</u> gains in fuel via automation and windfarm in terms of l/annum (and CO_2) saved.
- Develop a robust reporting system that refines the data where practical and allows relative numbers to be reported and compared.

- Refine BMS to capture energy consumption be stage to allow tracking of high energy use stages/items/activities.

The biggest recommendation:

Keep up the AWESOME work!

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Dr. Susan Krumdieck
Professor in Mechanical Engineering

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Appendix

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Approximate Diesel Fuel Consumption Chart

This chart approximates the fuel consumption of a diesel generator based on the size of the generator and the load at which the generator is operating at. Please note that this table is intended to be used as an estimate of how much fuel a generator uses during operation and is not an exact representation due to various factors that can increase or decrease the amount of fuel consumed.

Download Chart to PDF

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4.0
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5.0	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9
175	4.1	6.8	9.7	12.7
200	4.7	7.7	11.0	14.4
230	5.3	8.8	12.5	16.6
250	5.7	9.5	13.6	18.0
300	6.8	11.3	16.1	21.5
350	7.9	13.1	18.7	25.1
400	8.9	14.9	21.3	28.6
500	11.0	18.5	26.4	35.7
600	13.2	22.0	31.5	42.8
750	16.3	27.4	39.3	53.4
1000	21.6	36.4	52.1	71.1
1250	26.9	45.3	65.0	88.8
1500	32.2	54.3	77.8	106.5
1750	37.5	63.2	90.7	124.2
2000	42.8	72.2	103.5	141.9
2250	48.1	81.1	116.4	159.6

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