demandresponse

Report to the Electricity Commission

Electricity Efficiency

Compressed Air Systems Pilot Project

Public Report

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REFERENCES

APPENDICES

GLOSSARY

CAS	compressed air system
Commission	Electricity Commission
EECA	Energy Efficiency and Conservation Authority
ERP	Energy Reduction Project – a Fonterra initiative to reduce their energy intensity
IPENZ	Institution of Professional Engineers New Zealand
IRR	internal rate of return
KPI	key performance indicator
NZEECS	New Zealand Energy Efficiency and Conservation Strategy
M&T	monitoring and targeting
VSD	variable speed drive

EXECUTIVE SUMMARY

Compressed air systems (CAS) are common, energy intensive utilities found on most industrial sites. Compressed air is often referred to as the 'fourth utility' - behind fuel, electricity and water. Experience from several countries, including the USA, Germany and Britain, demonstrated that significant energy savings can be accrued through improving the design and operation of CAS. These international CAS programmes had produced energy savings of between 15- 40%.

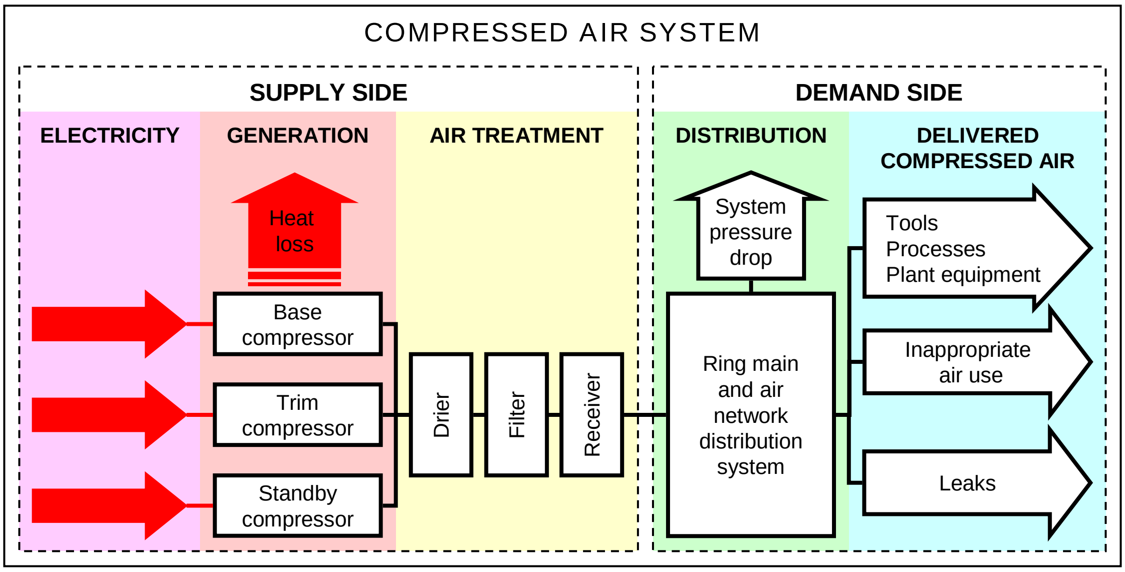
Recognising this, a pilot project was initiated by the Electricity Commission ("the Commission"), in association with Fonterra[1], to investigate whether compressed air systems in New Zealand presented an opportunity for significant electricity savings. There were four objectives for the pilot:

1. Establish scope of CAS electricity efficiency improvements (using Fonterra's CAS as a benchmark);
2. Determine the extent to which capital investment projects will result in improved electricity efficiency (using Fonterra CAS as a benchmark);
3. Identify whether Fonterra's CAS experience could apply over a larger sample of industries;
4. Establish if a general case exists in New Zealand for a "best practice" electricity efficiency programme for CAS.

Objective 1 – Scope of CAS Improvements

The model used for reviewing Fonterra's CAS is illustrated in Figure 1 – and is characterised by both supply-side (generation, treatment) and demand-side (distribution, end-use) components.

Figure 1: Components making up industrial CAS



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[1] Fonterra instituted their Energy Reduction Project (ERP) in 2002 with the stated aim to achieve a 10% reduction in their energy intensity (energy consumption per unit of production). Fonterra had launched their own internal programme for more efficient use of their compressed air systems and were therefore selected as a good candidate company for the purposes of this pilot project.

The pilot project conducted at Fonterra's Te Rapa site adopted a total system approach where supply-side and demand-side components were investigated and improved. In aggregate, the improvements to Fonterra's Te Rapa site CAS produced energy savings of 32%, summarised as:

- Improved air leak management (18% saving)
- Shedding peak air demands and inappropriate air use (6% saving)
- Reduction of CAS operating system pressures (4% saving)
- Improved compressor loading and control (4% saving)

Objective 2 – Capital Improvement Project

The next phase of the CAS improvements at Fonterra focused on capital investments to improve CAS energy efficiency. One of the objectives of this phase was to gauge capital investment effectiveness for typical energy reduction initiatives. This is an important consideration as the law of diminishing returns dictates that there will be a level of return that fails to meet a company's investment criteria (hurdle) and will not get approved on economic grounds.

A capital investment project for the Fonterra sites of Te Rapa, Edgecumbe and Whareroa was undertaken. The project involved the reconfiguration of air compressors across these three sites plus the purchase of two new 250 kW variable speed drive (VSD) compressors. This is summarised in Table 1. The capital cost of the project was $685,000 of which $225,000 was funded by the Commission in the form of a capital assistance grant.

Table 1: Compressor configuration across three Fonterra sites

Configuration	Fonterra Site	Compressor 1	Compressor 2	Compressor 3	Compressor 4
Before project	Te Rapa	(250)	(140)	(250)	*(110)
	Edgecumbe	Turbo (350)	*(150)	*(150)	
	Whareroa	Turbo (400)	(425)	5 x *(110)	
	2,775 kW	1,000 kW	715 kW	950 kW	110 kW
After project	Te Rapa	New VSD (250)	(250)	*(140)	
	Edgecumbe	New VSD (250)	(250)	*(110)	
	Whareroa	Turbo (400)	Turbo (350)	*(425)	*(110)
	2,535 kW	900 kW	850 kW	675 kW	110 kW

* Machine off but on standby. Brackets indicate air compressor power rating (kW)

The compressor reconfiguration was projected to deliver 2.4 GWh of electricity savings per annum which, using a typical industry electricity price gives a simple payback period of 3.2 years. The capital assistance from the Commission was expected to improve this simple payback period to 2.1 years - a figure typical of what many companies require of energy efficiency projects.

Outcomes from the capital improvement project at the Fonterra Sites:

- **Te Rapa:** Energy consumption for the CAS has reduced by 32% over the project duration. A quarter of these savings (8%) result from the VSD compressor.
- **Edgecumbe:** Compressor reassignment has so far resulted in electrical demand reduction of 59kW or 17%. Work to complete the project recommendations, air leak management and the measurement of the full effect of the VSD compressor installation is ongoing and is expected to deliver a further 71 kW in demand reduction.
- **Whareroa*:*** The installation of the turbo-compressor from Edgecumbe in not yet completed. Upon completion, the site will be able to operate on the one compressor which will provide improved specific power performance.

Objective 3 – Application to wider industry: Compressed Air System best practice

The operational improvements undertaken at Fonterra to improve energy efficiency have been successful. To establish whether this experience can be extended to the wider industry, a sample of ten Hamilton-based businesses were surveyed for CAS energy efficiency performance.

“Walk-through assessments” were completed at each site. These were not full CAS audits, but rather simple observations made by experienced personnel with an extensive background in compressed air system design and operation.

The collective potential reduction of CAS electrical demand over the 10 sites was assessed to be 224 kW. Taking into account the annual operating hours at each site, the aggregate CAS energy savings potential is estimated at 1.5 GWh.

Some conclusions from the Hamilton-based business surveyed with respect to establishing CAS best practice are:

- The ‘walk through assessments” were effective in assessing energy consumption patterns and possible improvements.
- There was a wide variation in installation standards; maintenance levels and supplier performance (equipment, and service).
- Larger sites (75kW and above) provided the most potential for energy savings with air compressors supporting 24/7 operations. These larger sites also have the resources to carry out recommendations for CAS improvements.
- Smaller sites (30kW or less) still have savings potential, through changes in end use and in system pipe work.
- Management on site needs to be involved and prepared to drive initiatives on site.

- System pressure reduction, removal of inappropriate compressed air uses and optimising compressor load conditions can provide energy savings with minimum investment cost. These could be considered part of continuous improvement.

- The feedback from industry is that manufacturers are looking for assistance and are supportive of CAS energy efficiency initiatives.

Objective 4 – Establish the basis for a nation-wide best practice programme

Based on the pilot work at Fonterra and the Hamilton industrial sites, it was concluded that a nation-wide CAS best practice programme could have two segments:

- Segment 1 – Industrial sites with CAS >75kW.

- Segment 2 – Mass market site with CAS <75kW

The larger industrial sites would benefit from a targeted CAS best practice programme along the lines of that achieved in the Fonterra pilot. Assuming the savings from the Fonterra pilot are typical, but acknowledging:

1. that few sites have installed capacity approaching the 500kW of Fonterra, and

2. 100% adoption of best practice will be most unlikely

Energy savings of 20% would be a reasonable target equating to 211 GWh of annual electrical savings through CAS best practice nation-wide.

Savings from the smaller, mass market industrial sites are expected to be more modest based on the experience from the Hamilton pilot. A more conservative 10% saving in CAS electrical demand is considered a reasonable expectation, yielding 35 GWh in annual savings. As this is around an order of magnitude smaller than the large industrial sector, involving many more sites, CAS best practice could be promoted through an awareness campaign including industry seminars.

Table 3: Expected impact of a national CAS best practice programme

Sector	CAS size	No. sites	Best practice promotion	Total CAS electrical demand	Targeted CAS electrical savings
Industrial	> 75kW	500	Operational and capital improvements	1,056 GWh	20% = 211GWh
Mass market	< 75 kW	6000	Awareness campaign	350 GWh	10% = 35 GWh

The prize from deploying CAS best practice in New Zealand is therefore expected to be savings of up to ~250 GWh per annum.

The conclusion from this pilot is that there is a reasonable basis for developing CAS best practice programmes that:

Promote and develop awareness of CAS energy efficiency

- Provide a foundation for increasing energy efficiency up-take by tackling the barrier of poor awareness of the energy savings potential.

- Develop relevant information and training material to support the programme for the mass market CAS users. Overseas programmes have demonstrated mass market advertising and awareness campaigns to be cost effective.

Focus CAS efficiency improvements on the total CAS system

- Develop the appropriate minimum standards for performance to “best practice” with both the equipment suppliers and end-users.

- Promote global experience that has shown significant energy savings can be achieved through cost effective practical improvements.

Help site management improve CAS performance

- Promote continuous improvement in the operation and maintenance, with a strong focus on measurement and the analysis of sustainable energy savings.

- Strongly encourage sites with large CAS capacity to install the necessary metering and reporting. Part of a future accreditation process could be the reporting of compulsory information on the energy performance of large CAS systems.

1. INTRODUCTION

1.1 Energy savings in compressed air systems

Compressed air systems (CAS) provide a significant opportunity for electricity efficiency in New Zealand industry. Compressed air systems are common to most industrial sites, often being referred to as the 'fourth utility' behind fuel, electricity and water.

Significant savings potential exists in the improvement of CAS[2]. The benefits of energy efficiency achieved in individual CAS would collectively provide large energy savings for the nation. The challenge is how to best realise and sustain these electricity savings.

A pilot project was initiated by the Electricity Commission ("the Commission") in association with Fonterra who had launched their own internal programme for more efficient use of their compressed air systems. Fonterra was willing to provide case study materials to the Commission. The pilot project team confirmed the value of pursuing electricity savings from compressed air systems throughout New Zealand industry.

1.2 Reporting the pilot project

Demand Response Limited has been involved in the CAS energy efficiency pilot project since 2004. This report outlines the progress achieved during the course of this pilot study. The report intends to highlight the key outcomes, illustrate the lessons learned and provide recommendations for moving forward with energy efficiency for CAS in New Zealand.

This report has been structured as follows:

1. Introduction
2. Background information on CAS in New Zealand
3. The objectives of the pilot project
4. Individual case study of energy savings for compressed air systems – Fonterra Te Rapa
5. Development of metering and reporting systems for CAS energy performance
6. Expanding the individual case study to a wider application (Hamilton sites)
7. The general case for realising energy efficiency from 'best practice' CAS in New Zealand
8. Conclusions of the pilot project into CAS electricity efficiency
9. Recommendations from the pilot project

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[2] To give some indication of the energy savings potential for CAS, a rule of thumb used internationally is that CAS represents 10% of the electrical power demand for industry.

2. THE BACKGROUND TO COMPRESSED AIR SYSTEMS ELECTRICAL EFFICIENCY

2.1 Electricity savings through compressed air systems energy efficiency

Despite advances in the efficiency of individual components, especially modern air compressors, the overall economic and energy efficiency of the total CAS system is often neglected. Wide scale energy audits from Europe and North America of CAS all report the potential for 15% to 40% gains in electricity efficiency of the CAS electrical demand. Despite energy efficiency measures being available, these savings are rarely realised in practice. Although there are many reasons for this, three important factors are:

- **Life-cycle cost:** The investment costs for the systems are geared towards minimum procurement and capital costs, with little consideration to operating costs. Total electricity consumption accounts for more than 75% of the life-cycle costs of an air compressor.

- **Responsibility:** Often, no one is directly responsible for the compressed air costs. The responsibility for compressed air systems is often spread over several management functions such as production, maintenance, procurement and accounting.

- **Visibility:** The electricity consumption in a compressed air system is often invisible to management and as a result there is seldom measurement or analysis of this consumption.

Figure 2.1 Life cycle cost of an air compressor

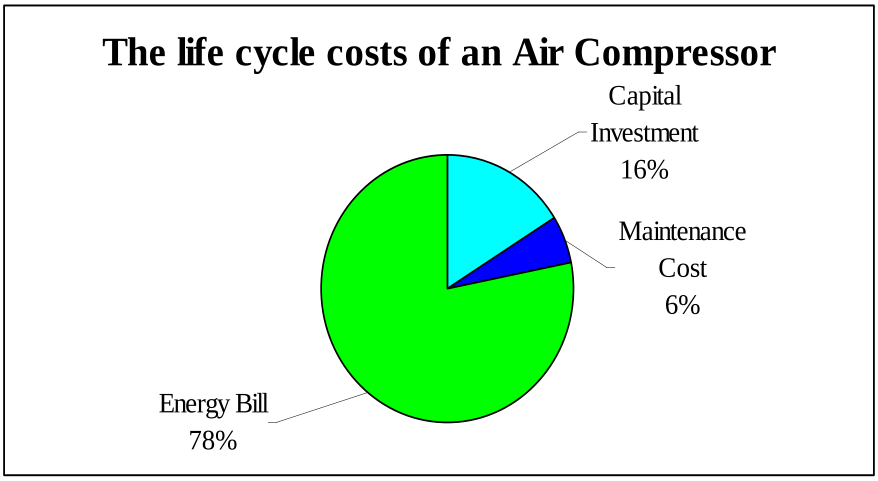
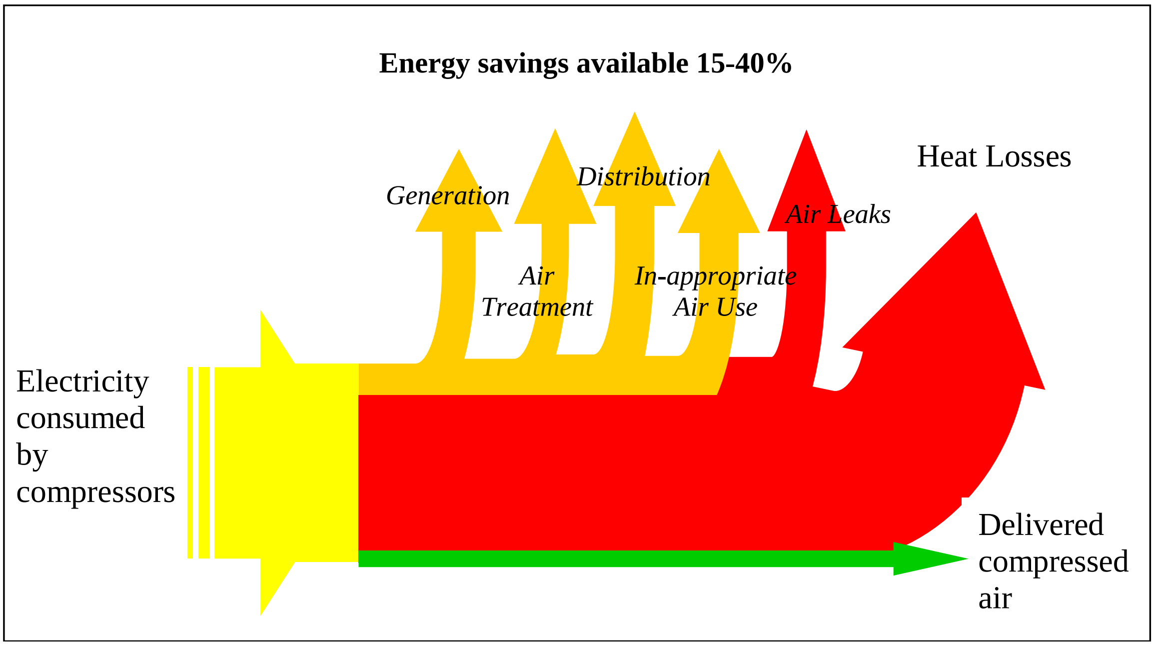


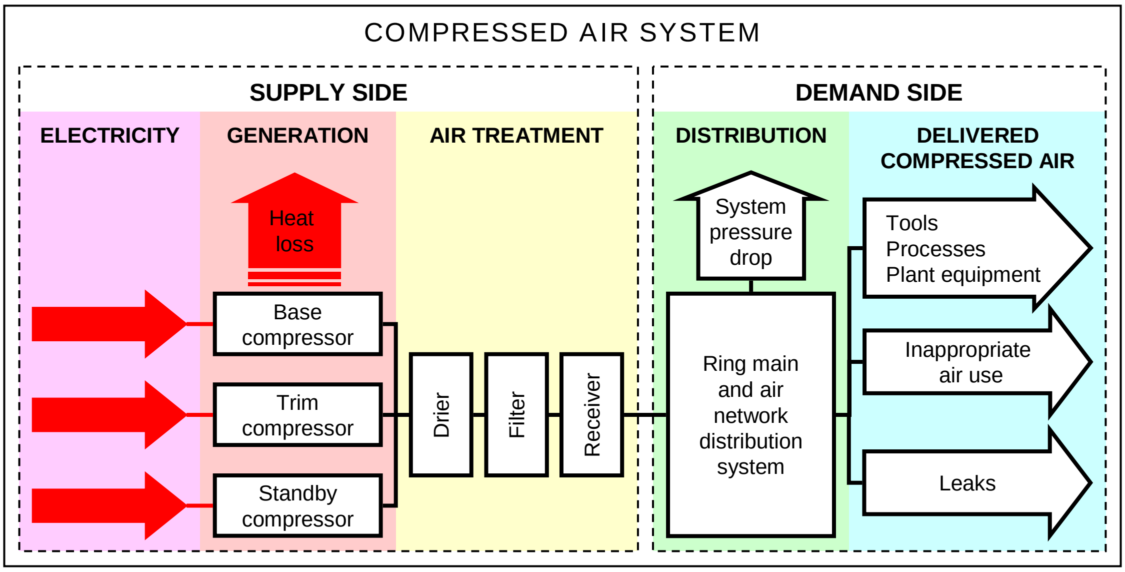
Figure 2.2 Energy flows of an industrial compressed air system



2.2 The demand side and supply side of compressed air systems

A CAS can be represented as having two distinct aspects: the “supply side” involves equipment and components that produce a supply of compressed air to a specified capacity, availability and quality; and the “demand side” which consists of the distribution network, end-users and losses (i.e. air leaks). Energy savings are available to both supply and demand sides of the CAS.

Figure 2.3 Industrial compressed air systems (supply and demand)



On the **supply side** are the equipment and components that generate compressed air. On large sites, multiple compressor installations are typically used to meet changing air demands. The air is treated, dried and filtered to meet the specifications required by a particular industry.

Supply side initiatives can require significant capital expenditure. For example, the substantial heat generated by air compression which is often lost to the atmosphere provides an opportunity for savings through heat recovery. Heat recovery can be made possible through the installation of heat exchangers and other equipment.

However, low cost energy savings are also achievable on the CAS supply side by reviewing:

- The operating set pressures to see if the plant can function satisfactorily at reduced pressure. (1 barg pressure drop corresponds to a 7% energy saving)

- The load/unload cycle of the compressors with the plant in full production can often present the opportunity to adjust the compressor pressure set points. This will minimise the offload running which continues to adsorb power whilst idling.

The **demand side** includes the compressed air distribution system through to the different compressed air users and production processes. Reducing air leakage, removing inappropriate air use and eliminating pressure drops in the distribution system all provide cost effective savings opportunities. These initiatives offer electricity savings by reducing the generation requirement of compressors.

Clearly there is a strong interaction between the supply and demand sides of CAS. Therefore a **"total systems"** approach should be adopted in order to produce sustainable energy savings. The involvement of all parties associated in industrial CAS (equipment suppliers, service providers and site personnel) is critical to the success of energy efficiency in CAS.

3. THE OBJECTIVES OF THE PILOT STUDY

3.1 Objective 1 - Quantify electricity efficiency improvements in a Fonterra CAS

Fonterra, New Zealand's largest company has many industrial processing sites throughout the country. Many of their processing sites have reasonably large and complex CAS in operation. Fonterra is committed to energy reduction at a corporate level and senior management has outlined strategic plans for reducing Fonterra's energy intensity (energy consumed per unit of production).

The present investigation into operational (practical) improvements for increased electricity efficiency in CAS was a good fit with Fonterra. The pilot team set out to quantify the energy savings available in the identified operational improvements. Fonterra (Te Rapa) provided an example of what can be achieved with a typical industrial compressed air system.

3.2 Objective 2 - Determine the extent to which a specific capital investment results in improved electricity efficiency in a Fonterra CAS

The pilot project sought to understand how industrial companies would overcome investment barriers in projects that, while delivering sustainable electricity savings, produce lower rates of return than is desired by business.

An air compressor investment project was identified within Fonterra that would improve electrical energy efficiency. The objective was to undertake the capital improvement and analyse the savings and returns against typical investment decision thresholds. The results of this analysis provide a basis for establishing the circumstances where funding assistance with this type of energy efficiency project may be viable.

3.3 Objective 3 - Identify whether the Fonterra CAS experience could apply over a larger sample of industries

The early site work completed at Fonterra provided the pilot project team with several examples of operational improvements that lead to energy savings. This suggested that the savings initiatives instituted at Fonterra (Te Rapa) could be replicated across industry.

The pilot project visited a number of other industrial sites to confirm if similar energy savings potential existed. The successful extrapolation of energy savings achieved at one site to a wider industrial context would provide significant energy savings potential for New Zealand.

3.4 Objective 4 - Establish if the general case exists for a nationwide best practice programme of electricity efficiency for CAS

The Commission is interested in the feasibility of a nation-wide best practice programme for CAS electricity savings. The aim of this part of the research was three fold:

1. Identify the barriers to the adoption of energy efficient practice using evidence gathered from local and international experience.
2. Develop an understanding of the scope and potential for energy efficiency savings in CAS across New Zealand industry.
3. Prepare the foundations for a strategy for best practice programme for CAS that builds upon the findings of this pilot project.

4. FONTERRA TE RAPA - AN INDIVIDUAL CASE STUDY

4.1 Introduction to the Fonterra CAS case study

Fonterra instituted their Energy Reduction Project (ERP) in 2002 with the stated aim to achieve a 10% reduction in Fonterra's energy intensity (energy consumption per unit of production). This initiative was originally piloted at two sites: Lichfield (Waikato) and Clandeboye (Canterbury), before rolling-out further to the Whareroa (south Taranaki) and Te Rapa (central Waikato) sites, and then to the remainder of Fonterra's sites in New Zealand.

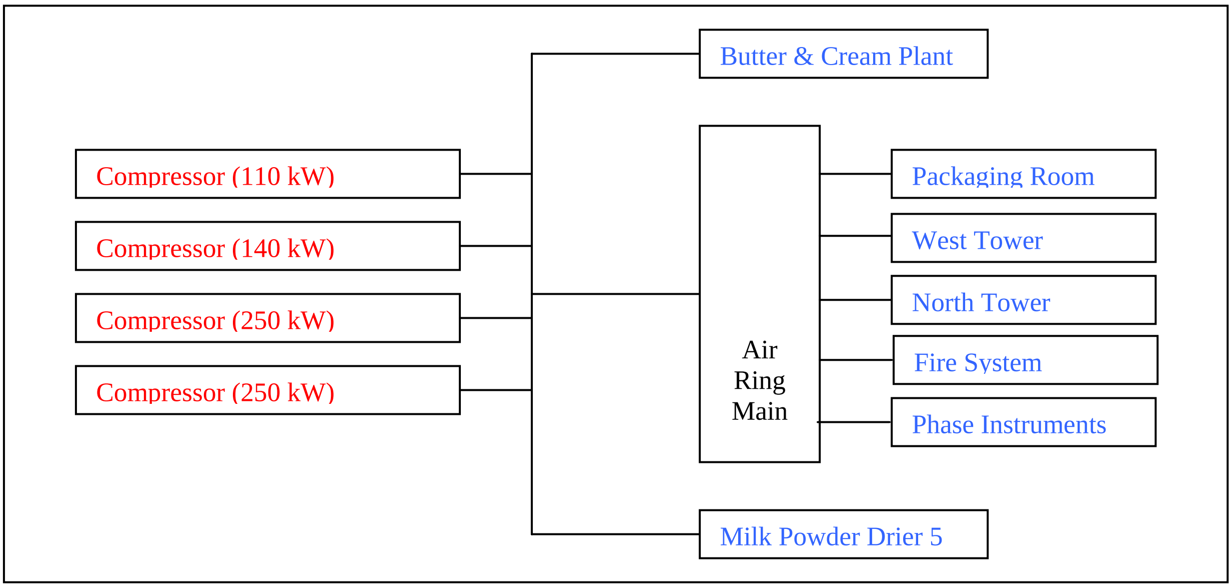
As part of the ERP a compressed air audit project started during the 2004/2005 dairy season at the Te Rapa site. The University of Waikato was funded by EECA to assist with the compressed air work at the Fonterra Te Rapa site in Hamilton[3].

As a result of this air audit project, energy audits were undertaken at other Fonterra sites in the Waikato. The aim was to improve the existing methods for the operation of CAS, and the control and selection of new compressor installations. Observations of the research included noting that there was a lack of accurate metering (air flow in particular).

The Fonterra Te Rapa milk powder site was used as the CAS case study to illustrate what is possible in making sustainable electricity savings if there is a long-term commitment to continuous operational improvements. This case study follows the progress made on site at Te Rapa from the 2003/2004 dairy processing season, and builds upon research funded by EECA.

4.2 Fonterra Te Rapa site summary

Figure 4.1 Schematic of the Te Rapa CAS during the 2003/2004 dairy season



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[3] See Reference No. 1

Fonterra's Te Rapa site processes in excess of 6000 cubic metres of milk each day, delivering a range of products including milk powder, butter and cream. The processing season is approximately 270 days long. Milk processing rates at Te Rapa have a bearing on the energy usage of the CAS and are important when comparing CAS performance over the various seasons. Historic production information is used later in this study to set the baseline for CAS efficiency improvement measurement.

4.2.1 Supply side of the Te Rapa CAS

In the dairy season of 2003/2004 season there were four air compressors in service at Te Rapa:

- Two 250 kW machines were used throughout that season and at the time of the pilot were 6 and 15 years old.

- The 140 kW and 110 kW units are 7 years and 28 years old respectively and remained as back-up machines to cover any event where a primary compressor is out of service. However, the 140 kW compressor has had limited use as a result of a Fonterra ERP initiative, completed before this pilot started. The 140 kW compressor was used in the 8 week off product period.

Table 4.2: Air compressors in service at Te Rapa at the beginning of the pilot project

Compressor	Age (yrs)	Capacity (m3/hr)	Rated (kW)	Loaded (kW)	Unloaded (kW)
110 kW	28	1,150	110	120	30
250 kW	15	2,250	250	250	45
140 kW	7	1,150	140	140	30
250 kW	6	2,250	260	260	45

4.2.2 Demand side of the CAS at Te Rapa

The main end uses for compressed air at Te Rapa are:

- Process Valves – Pneumatically powered valves.

- Instrument Air – Air used to power hand held tools and other instruments.

- Bag House (Drier 5) – Compressed air pulses to blow filter bags clean.

- Nozzle cleaning (Driers 4 & 5) – Pressure pulses to keep nozzles clear.

- Packing Lines – A combination of pneumatic actuated cylinders.

4.3 Fonterra CAS improvements

Fonterra has undergone an internal initiative for improving their CAS and achieving sustained improvement in energy intensity. Over the last three dairy seasons (2004-2007) Fonterra has implemented several operational improvements to both the supply and demand sides of the Te Rapa CAS.

The compressed air system at Te Rapa has had an energy reduction of 32%. This saving has been achieved through operational improvements and capital improvements. The reduction of electrical demand (kW) has been adjusted for the variance in production levels.

4.3.1 Establishing a baseline level of performance for the Te Rapa CAS

A baseline level of CAS energy performance using the available 2003/2004 data was established, using a regression analysis, to establish the correlation between CAS energy demand and production levels. This relationship allows the baseline electrical demand to be projected for a given production rate.

For the regression analysis, 2003/2004 season average daily CAS electrical demand was divided by the corresponding daily production rate to establish a "normalised demand" (kW per unit of production). Normalised demand was then plotted against daily production. A robust correlation[4] was seen to exist, with a regression coefficient of 0.9501.

This analysis enables an estimate of baseline electrical demand for any given production level. The approach was adopted because compressed air flow metering data for the 2003/2004 year was not available to establish the correlation between compressed air flow and processing rates or compressor demand.

Table 4.3 summarises the electrical energy savings at Te Rapa calculated against the baseline correlation and adjusted for production variances.

Table 4.3 Comparison of projected and actual CAS demand from a 2003/2004 baseline

Fonterra Dairy Season	2003/2004	2004/2005	2005/2006	2006/2007
Expected demand (based on production rates)	517	526	524	479
Actual electrical demand (kW)	515	441	336	375
Offset for the new packing facility (kW)				(59)
Electrical demand - Actual (kW)	515	441	336	316
Electrical demand - Savings (kW)	2	85	188	201
Percentage electricity savings (from 2003/2004 baseline)	0%	16%	36%	39%

4.3.2 Impact of new packing facility at Te Rapa

The dynamic nature of manufacturing plants means that CAS are often forced to adapt and adjust to meet changing compressed air demand. This can result in unforeseen and additional load upon the CAS supply side equipment. After the last air flow audit completed on site (in the 05/06 season) the demand for air increased significantly due to the installation of a new packing facility at Te Rapa.

Table 4.4: Change in the electrical load from new plant packing facility

Change in the electrical load from new plant packing facility		
Additional demand for air	524	m^3/hr
Additional demand for air	8.73	m^3/min
Specific power at time of the addition of new plant facility	6.74	kW/(m^3/min)
Approximate increasing in electrical load	58.86	kW

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[4] R value > 0.95, this is a statistical indicator of a strong correlation.

The new facility increased compressed air demand by 524 m^3/hr, or 17.5% of the total 2991 m^3/hr compressed air demand at that time. This added load is quantified at 58.9 kW. The increased load impacted on the total CAS energy consumption and has therefore needed to be offset so that the impact of any operational and capital improvements could be accurately assessed.

The impact of the new packing facility on compressed air flow is summarised in the following Figure 4.2 and Table 4.5 across the period covering the 2003/2004 and 2006/2007 dairy seasons.

Figure 4.2 Impact of new plant on the operational improvements to Te Rapa CAS

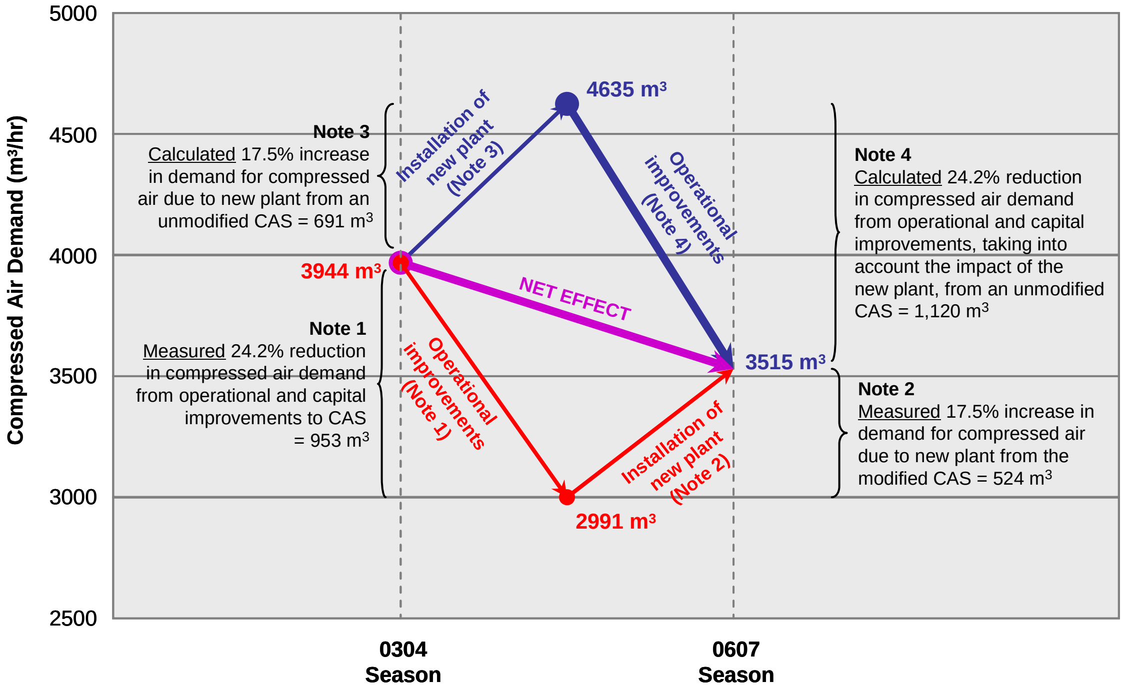

Table 4.5: The impact of the new packing facility on energy savings

The impact of the new packing facility on energy savings		
Air flow rate of CAS in baseline year (viz. 2003/2004)	3944	m^3/hr
Estimated flow of CAS in baseline year with the (new packing facility offset)	4635	m^3/hr
Measured flow of CAS in 2006/2007 after operational improvements	3515	m^3/hr
Net change in demand for compressed air through operational improvement	1120	m^3/hr
Estimated flow and power savings through reduced air demand 2006/2007	24.2	%
Normalized power demand at 2003/2004	517	kW
Calculated impact of new packing facilities on 2003/2004 power demand	59	kW
2003/2004 normalised power demand including offset for new packing facilities	576	kW

4.3.3 Distribution of the electrical energy savings at Te Rapa:

The operational and capital improvements have delivered 32% electricity savings from the 2003/2004 baseline in four main areas:

1. Air leak management (operational improvement - demand side);
2. Shedding peak air demand and inappropriate air use (operational improvement - demand side);
3. Improved compressor control (capital improvement - supply side);
4. Reduction of CAS operating pressure (capital improvement - supply side).

In 2004 the estimated total free air delivery of the Te Rapa CAS was 3944 m^3/hr. The demand for air since 2004 until the 2005/2006 Season has been reduced by approximately 1000 m^3/hr (in the range of 953 to1120 m^3/hr depending on how the impact of the new facilities is accounted for) to 2991 m^3/hr. This equates to percentage flow saving of 24%. The demand reduction of compressed air is an example of a demand side operational improvement. There are two obvious improvements at Te Rapa that have resulted in this 24% flow saving:

1. A successful air leak management programme (105 kW); and
2. The control of the inappropriate uses of air (35 kW).

Table 4.6: Changing the plant has had the net effect on reducing the air demand

Changing the plant has had the net effect on reducing the air demand		
03/04 normalised power demand including new plant offset	576	kW
Estimated flow and power savings through reduced air demand 2006/2007	24.2	%
Power savings achieved through air demand reduction (24.2%)	139	kW
Power savings from air leak removal 75% of the net energy savings	105	kW
Power savings from the removal of artificial demand 25% of the net energy savings	35	kW

AREA 1: ENERGY SAVINGS THROUGH AIR LEAK MANAGEMENT

The single most significant improvement to CAS at Fonterra was savings through effective management of air leaks. Of the 1,000 m^3/hr reduction in air demand, air leak management was responsible for approximately 75% of the savings made. As a point of reference the typical energy losses as a result of air leaks is summarized in Table 4.7.

Air leak management relies on accurate leak detection and prompt remediation. Significant work has been achieved in the practices of air leak detection[5].

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[5] This development is explained in the lessons learned at Fonterra Section 4.7.

Table 4.7: The impact of air leaks on CAS energy loss[6]

Hole Diameter	Air leakage rate at 6 barg		Power loss at the compressor (kW)
	(l/s)	(m^3/hr)	
1 mm (pin head)	1	4	0.3
3 mm (match head)	10	36	3.1
5 mm	27	97	8.3
10 mm	105	378	33.0

AREA 2: ENERGY SAVINGS THROUGH REMOVING INAPPROPRIATE AIR USE AND DEMAND PEAKS

The remainder of the compressed air demand side savings can be attributed to the removal of inappropriate air use or 'artificial demand' as it is more commonly referred to. Of the 1000m^3/hr of reduced air demand it is estimated that 25% or (250m^3/hr) of this has been through the removal of artificial demand.

Artificial demand at the Te Rapa milk processing plant includes:

- when compressed air is used for cleaning or cooling;
- where air agitation is used in place of blowers (which can be just as effective); and
- Using air jets to eject products residue from lances where intensifying nozzles provides a suitable alternative.

AREA 3: IMPROVED COMPRESSOR CONTROL

The introduction of the VSD compressor has resulted in energy savings through elimination of periods when the compressors ran unloaded. The compressors at Te Rapa were running unloaded for extended periods due to the cyclical production demand and the need to maintain system pressure. In this mode, compressors continue to use 25-30% of the full load power.

In a typical day during the 2003/2004 each of the four air compressors ran unloaded a high proportion of the time, resulting in significant wastage of electrical power. During the 2006/2007 season, the remaining three air compressors had their unloaded time eliminated, through the introduction of a VSD which enabled a complete match of supply to the air demand

The improved control regime of the compressors is responsible for energy savings of 23 kW in CAS electrical demand.

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[6] Reference Atlas Copco - Compressed Air Manual

Table 4.8: Unloaded compressor hours in 2003/2004

Unloaded compressor hours in 2003/2004 (prior to the operational, demand-side improvements)			
Compressor	Unloaded kW	% Unload Time	CAS Unloaded kW
110	30	2%	1
250	45	15%	7
140	30	45%	14
250	45	4%	2
Total			23
Unloaded compressor hours in 2006/2007			
Compressor	Unloaded kW	% Unload Time	CAS Unloaded kW
VSD 250	0	0%	0
140	30	0%	0
250	45	0%	0
Total			0

AREA 4: ENERGY SAVINGS THROUGH THE REDUCTION OF SYSTEM PRESSURES

The introduction of the VSD compressor enabled system pressures in the Te Rapa network to be lowered. This is achieved through improved compressor control enabling the impact of surging pressures to be minimized, which in turn allows the compressor set points to be lowered. This reduces the power consumed by the motor driving the air compression.

The installation of additional air receivers (storage capacity) adjacent to high demand processes (air pulsing at the bag house) also assisted in the pressure reduction. This additional storage capacity helps to minimise the impact to the local pressure and helps reduce the size of the peak.

Table 4.9: Power savings achieved through reduction in system pressure

Power savings achieved through reduction in system pressure		
Recorded system pressure in Fonterra season 2003/2004	7.1	bar
Recorded system pressures in Fonterra season 2006/2007	6.5	bar
Average system pressure reduction (barg)	0.6	bar
Compressor power savings for 1 bar pressure drop	7	%
Power savings at Te Rapa through pressure change	4.2	%
Compressor power consumption during the baseline seasons 2003/2004	517	kW
Compressor power consumption adjusted for new packing plant (+59kW)	576	kW
Electrical savings achieved - pressure reduction	24	kW

During the 2003/2004 season air pressure readings were conducted on site by operators and manually logged. These data points were then averaged to provide a basic outline of the compressor output pressures. The recorded pressures were at various points throughout the factory across a range of times.

The pressure readings for the 2006/2007 season are now automatically recorded by metering at the compressor room. The Te Rapa network has had on average, a system pressure reduction of 0.6 barg over the last three seasons. This relates to a saving of 4% which is considered a supply side saving.

4.3.4 Summary of energy savings

Taking the most conservative approach to these data, a claim of a 32% energy saving is justified as a result of operational and capital improvements to the Te Rapa site CAS.

Table 4.10: Summary of CAS improvements

CAS energy efficiency improvements	Energy savings contribution	Total energy savings	CAS electrical demand savings (kW)	Nature of CAS improvement
Air demand savings - air leak management	56.2 %	18.1 %	105	operational
Removal of artificial air demand	18.7 %	6.1 %	35	operational
Improved compressor control and loading	12.3 %	4.0 %	23	capital
Reduction of systems pressures	12.8 %	4.2 %	24	capital
Total improved CAS performance	100 %	32.4 %	187	net

Aggregating each of the improvement areas, the CAS energy improvements have resulted in a saving of 187 kW, or 32 % of the 2003/2004 baseline of 576 kW (517kW + 59kW additional load contributed by the new plant). This compares very favourably (i.e. within 7%) with the savings predicted by the regression analysis of 201 kW.

The net electrical demand savings (187 kW) on the Te Rapa CAS, resulting from operational and capital improvements, equate to annual energy savings of 1.4 GWh per annum (based on 308 days running for 24 hours per day).

4.4 Fonterra capital investment project

4.4.1 Background

Many operational improvements involve only modest costs and give high returns (savings). A second stage of the Fonterra energy efficiency improvements focused on capital investment to improve the energy efficiency of CAS.

The key objective of this stage was to gauge capital investment effectiveness for typical energy reduction initiatives. This is an important consideration as the law of diminishing returns dictates that the cost benefit ratio of capital investment becomes decreasingly attractive. There will be a level of return that fails to meet a company’s investment criteria (hurdle) and will not get approved on economic grounds.

The aim of the project was to improve the energy efficiency and the performance of Te Rapa, Edgecumbe and Whareroa compressed air systems, through the installation of two new variable speed drive (VSD) compressors and relocating existing ones.

4.4.2 Summary of the investments and outcomes

The Fonterra sites of Te Rapa, Edgecumbe and Whareroa undertook to re-configure their mix of air compressors. The new configuration involved the purchase of two new air compressors with VSD technology.

The project is expected to deliver 2.4 GWh of electricity savings per annum. The cost of the capital improvement project was $ 685,000. The Commission committed to $225 000 in capital assistance to see the energy savings eventuate.

The benefits and outcomes of the capital investment project are tabulated in Table 4.11.

The capital investment project was instigated by Fonterra in October 2005. The new VSD compressor was installed at Te Rapa in December 2006. Between the capital project design and the compressor installation changes to the manufacturing facility occurred. A new automated packing line was installed in November 2006. The new packing facility contains pneumatic components which have increased the demand for compressed air. The impact of this load increase has been quantified[7]. Permanent metering of air flow rates and the electrical metering of compressors was installed in February 2007.

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[7] Section 4.5

Table 4.11: Benefits and outcomes of the capital investment project

The new compressor configuration will provide more robust and reliable CAS for Fonterra	
Proposed benefit	**Project outcomes**
Improved production capability and flexibility Secure contingency arrangements	New plant added by Fonterra has been absorbed without cost by the new configuration Standby compressor availability
Compressor generation (supply side) more closely aligned to air usage (demand side)	
Proposed benefit	**Project outcomes**
Less unloaded compressor hours Electricity Savings	Compressors at Te Rapa are running unloaded for less than 1% of the time 7% electrical energy savings have achieved.
Improved CAS efficiency	
Proposed benefit	**Project outcomes**
Improved Specific power performance Reduced electricity consumption	Compressor efficiency has improved Specific power consumption has improved
VSD compressors offering improved pressure control leading to reduced system pressures	
Proposed benefit	**Project outcomes**
Electricity savings through system pressure reduction. Improved longevity of system components	System Pressure reduction has been achieved. Reduced maintenance costs.
Reduced air compression surpluses at Edgecumbe leading to reduced air flow losses	
Proposed benefit	**Project outcomes**
Eliminate the venting of compressed air leak detection and remediation	Compressor reconfiguration. Flow losses continue to be eliminated
Removing redundant compressors from operation and reducing maintenance costs.	
Proposed benefit	**Project outcomes**
Reduced maintenance costs	Maintenance costs are reduced
Ensure the financial viability of the capital investment project	
Proposed benefit	**Project outcomes**
Fonterra investment criterion met. Investment cost = << $60/MWh for the Commission	Project not fully completed, savings opportunities yet to be exploited

4.4.3 Capital investment project scope

The pilot project investigated the investment of a new VSD compressor to replace a fixed speed air compressor (250 kW) at Fonterra's Te Rapa site. VSD compressors allow for the compressor to operate more efficiently, through the matching of supply to demand. This reduces the average electrical power consumption of the compressor.

However, this stand-alone investment in a new VSD air compressor at Te Rapa would not meet Fonterra's capital investment criteria. By achieving an optimised compressor mix across the Fonterra sites of Te Rapa, Edgecumbe and Whareroa, investment in energy efficiency projects becomes more attractive due to:

- **Scale efficiencies:** significant, aggregated electricity savings became possible by considering three sites rather than just one

- **Minimising capital expenditure:** by reallocating compressor service across the sites minimised the need to invest in new equipment as existing compressors could be redeployed to alternative, better matched service.

The scope for this pilot project is detailed below:

1. Installation of two new 250kW VSD air compressors for energy efficient top-end performance at Te Rapa and Edgecumbe.

2. Relocation of the large turbo-air compressor at Edgecumbe to the Whareroa site where it will run fully loaded as a base load machine.

3. Movement of the redundant 250 kW machine from Te Rapa to Edgecumbe where it will run as a base load machine.

4. Making redundant the old 110 kW at Te Rapa, compressor 3 at Edgecumbe and four 110 kW machines from Whareroa.

5. Installation of new air flow and electrical metering is important to quantify the projected energy savings.

Table 4.12: Compressor configuration across three Fonterra sites

Configuration	Fonterra Site	Compressor 1	Compressor 2	Compressor 3	Compressor 4
Before project	Te Rapa	(250)	(140)	(250)	*(110)
	Edgecumbe	Turbo (350)	*(150)	*(150)	
	Whareroa	Turbo (400)	(425)	5 x *(110)	
	2,775 kW	1,000 kW	715 kW	950 kW	110 kW
After project	Te Rapa	New VSD (250)	(250)	*(140)	
	Edgecumbe	New VSD (250)	(250)	*(110)	
	Whareroa	Turbo (400)	Turbo (350)	*(425)	*(110)
	2,535 kW	900 kW	850 kW	675 kW	110 kW

* Machine off but on standby. Brackets indicate air compressor power rating (kW)

Table 4.12 illustrates the compressor configuration before and after the capital improvement project. The compressor sizes are colour coded for clarity. The installed compressor capacity (kW) is reduced as a result of the project, and the ratio of online to 'standby' compressor allocation is improved.

4.4.4 Projected electrical demand savings for Fonterra CAS

The projected electrical demand savings across the three Fonterra sites is 325 kW and is summarised in the following table. The original electrical demand values represent the electrical load at the time of the project design in October 2005. Energy savings were expected to result from the Fonterra CAS through:

- Reduced system pressures from improved compressor control;
- Removal of unloaded compressor hours by improving generation capacity with air demand;
- The realization of air leak remediation at Edgecumbe.

Table 4.13: Compressor configuration before and after capital improvement project

Fonterra Site	Original CAS demand (kW)[(a)]	Proposed CAS demand (kW)	Projected demand savings (kW)	Annual energy savings (GWh)
Te Rapa	400	335	65	0.48
Edgecumbe	350	200	150	1.11
Whareroa	850	740	110	0.81
All sites	1600	1275	325	2.4

Note: (a): Te Rapa data based on site-wide measurements conducted October 2005; other sites based on Q4 2005 estimates.

4.4.5 Energy and cost savings projected through capital investment

The capital investment project was expected to save 2.4 GWh of electricity consumption per annum across all three Fonterra sites and, as outlined in Table 4.14, provide energy and maintenance cost reductions, estimated at $213,000 per annum.

Table 4.14: Energy and cost savings from the capital improvement project

Capital improvement - projected energy savings		
Electrical demand of the original compressor mix	1600	kW
Electrical demand of the reconfigured compressor mix	1275	kW
Projected demand savings over the Te Rapa, Edgecumbe and Whareroa CAS	325	kW
Number of run hours year (based upon an average of 308 peak days)	7392	h/year
Annual energy savings	2.4	GWh
Capital improvement - projected cost savings		
Total projected energy savings	2.4	GWh
Project electricity cost savings (using a typical electricity rate for industry)	$173,000	pa
Maintenance cost savings (Each compressor has maintenance cost at $20K pa)	$40,000	pa
Total cost savings	$213,000	pa

4.4.6 Cost of the capital investment project

The complete budgeted capital cost for the proposed project was $685,000. The capital cost for the project was estimated by mechanical engineering contractors[8] and Fonterra project engineers.

Table 4.15: Cost breakdown of capital investment project budget

The capital investment project costs	
Two 250kW VSD compressors[a]	$400,000
Installation and relocation of all air compressors	$155,000
Engineering works (civil/mechanical/electrical)	$35,000
Air flow metering at Whareroa [b]	$15,000
Project management	$50,000
Contingency allowance	$30,000
Total	$685,000

Note: (a) A budget price. This may be slightly different to final actual cost due to competitive tender process.
(b) Te Rapa and Edgecumbe have adequate air flow metering.

4.4.7 Introduction to the funding of the Fonterra capital investment project

Investment in new equipment for industrial sites like Fonterra plants is costly and can be difficult to justify on economic grounds – particularly when project funds are scarce and energy efficiency projects must compete with other value-adding projects in a company's investment portfolio. Indeed, experience in New Zealand and abroad indicates that the investment returns from capital expenditure on energy efficiency projects can still be marginal even when other savings from heat recovery and reduced maintenance are accounted for.

If companies were able to receive financial assistance for this capital outlay, projects become more viable. This leads to energy savings projects being more likely to meet investment criteria and to be undertaken, and the energy savings potential to be realised. This is a benefit to both the individual plant operation and the greater national cause.

4.4.8 Improving the financial performance of investment into the capital project

Using the $213,000 saving with a $685,000 capital cost, the project has a 3.2 year simple payback and an IRR (using a 10 year life) of 29%.

Even though this return was generated by leveraging scale efficiencies and minimising capital expenditure, this payback will, for many companies, fail to meet the hurdle rate for discretionary expenditure. This is typical of many companies where there are limited funds available for capital improvements and each project has to be justified against a slate of other project opportunities which offer higher returns. Table 4.16 summarises the return on investment using a typical industry electricity price:

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[8] The savings have been estimated from the available plant historical data, from the previous work carried out on this pilot project and under the common theme work with Fonterra. Reference: Mechanical Technology Limited (MTL), Re: Edgecumbe, Te Rapa and Whareroa air compressor rationalisation budget estimate, a report to John Herbert at Fonterra, 02 February 2006.

Table 4.16: Return on investment for capital improvement project

The project return	
Capital investment amount	$685,000
Annual cost savings	$213,00
Payback rate (years)	3.2
Project internal rate of return (IRR)	29%

4.4.9 Improved financial returns of the project with capital assistance

Ideally, energy efficiency gains will hold the same value as supply-side alternatives for energy delivery[9]. In the longer term, energy savings are more cost effective than the financial and environmental costs of generating additional electricity.

This project requires the strategic allocation of funding (via the Commission) to help meet the capital cost to make it viable to Fonterra. There are benefits to both parties, if the capital assistance fund makes the capital investment project eventuate. A successful capital assistance fund could provide a model for future roll out of energy savings projects.

This pilot project focuses on ensuring simplicity with a capital assistance fund. A capital investment subsidy from the Commission was used as demonstration concept during this pilot project. More complex funding structures (such as recovering the capital fund through the re-distribution of energy savings) were not considered by the Commission because of their inability to achieve many of the wider benefits in the short-term[10].

4.4.10 Capital investment project versus the alternative of new power generation

The basic model for the capital assistance pilot was the Commission offering assistance of $225,000 (33% of the capital cost), enabling Fonterra to meet its investment criterion and thereby sanctioning the project.

Power savings can be considered as a form of substituted generation. On a simple, discounted basis (at a 10% discount rate) over 10 years, the 24 GWh of energy saved equates to around $970,000 required to be invested in the equivalent of new power generation (refer to Table 4.17). The capital cost of the pilot project, when compared to the estimate for the long run marginal cost of new generation of $60/MWh, delivers $29/MWh.

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[9] See References No. 2 and 3.

[10] Stephen Drew and Allan Kerr, Demand Response, "Innovation for the Compressed Air Pilot Project", a Memo to the Electricity Commission, 13 December 2005.

Table 4.17: Required return on investment for capital improvement project (at a 10% discount rate)

Year	Saving (GWh pa)	Generation: $60/MWh	Discount Factor	Present value
1	2.4	$144,000	1	$144,000
2	2.4	$144,000	0.9091	$130,909
3	2.4	$144,000	0.8265	$119,009
4	2.4	$144,000	0.7513	$108,189
5	2.4	$144,000	0.6830	$98,353
6	2.4	$144,000	0.6209	$89,412
7	2.4	$144,000	0.5645	$81,284
8	2.4	$144,000	0.5132	$73,895
9	2.4	$144,000	0.4665	$67,177
10	2.4	$144,000	0.4241	$61,070
Total				$973,299

Table 4.18: The Commission's capital investment ratios

The Commission's capital investment	
Electricity savings over 10 years	24 GWh
Total project capital cost	$685,000
Fonterra's capital contribution	$460,000
Electricity Commission's capital assistance fund	$225,000
Marginal cost for the electricity saved	$29/MWh

4.5 Fonterra – Capital investment project outcomes

4.5.1 Te Rapa site

SPECIFIC POWER

Specific power is a key a key performance indicator for CAS energy efficiency. At Te Rapa, specific power has steadily improved over the course of this pilot study. The specific power reduction at Te Rapa between seasons 2003/2004 and 2005/2006 was achieved through the improvements detailed in Fonterra Stage 1. The improvements in specific power between the 2005/2006 season and the 2006/2007 season are attributed to the capital improvement project. CAS delivering air with a specific power below 6.5 kW/(m^3/min) is considered by the CAS supply industry as an energy efficient CAS[11].

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[11] See Appendix A.

Table 4.19: Improvement in CAS specific power

Dairy season	Power (kW)	Flow (m^3/hr)	Flow (m^3/min)	Specific power (kW/[m^3/min])
Fonterra 2003/2004	515	3944	65.73	7.84
Fonterra 2004/2005	441	3594	59.89	7.36
Fonterra 2005/2006	336	2991	49.85	6.74
Fonterra 2006/2007[12]	375	3515	58.58	6.40

IMPROVED COMPRESSOR CONTROL

The introduction of the VSD compressor has resulted in energy savings through elimination of the offload running time of the compressors. At the time of this report writing 51 kW of reduction has been achieved at the Te Rapa site and is summarised in Table 4.20. This level of savings will result in electricity consumption savings of 0.4 GWh per annum.

The Te Rapa site warrants specific elaboration as there was numerous changes to the CAS, during the pilot work, the period spanning the 2003/2004 and 2005/2006 dairy seasons. By improving the demand-side performance of the CAS through removal of air leaks and artificial demand, the overall demand for compressed air decreased during this time. This was one of the key aims of the pilot project. However, this reduced load meant that the Te Rapa compressors spent a greater proportion of their time unloaded, The unloaded compressor run hours actually *increased* from the original 2003/2004 dairy season to the time of the capital project design.

The reconfiguration of the compressors and introduction of new VSD units were expected to deliver the energy savings as summarised in Table 4.20. This table also includes the actual unloaded conditions during the 2006/2007 season.

Table 4.20: Te Rapa Compressor run conditions (Sept-Oct 2005) expected to change as a result of capital investment project compared to actual 2006/2007 season.

Compressor	Projected change	Load (kW)	Load time	Unload (kW)	Unload time	Electrical demand reduction (kW)
250	Remove compressor	250	16%	45	9%	44
140	Remove unloaded hours	-	-	30	5%	3
250	Remove unloaded hours	-	-	45	9%	4
Total						51
Unloaded compressor hours in 2006/2007						
Compressor		Unloaded (kW)		Unload time		CAS unloaded (kW)
VSD 250		0		0%		0
140		30		0%		0
250		45		0%		0
Total						0

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[12] See Appendix B & C.

It should be noted that the 23 kW of savings reported in section 4.3.3 (Area 3) is a net figure. It does not take into account the increase in unloaded compressor time that resulted from the demand-side improvements, due to removal of air leaks and artificial demand. This caused a greater supply and demand imbalance and increasing the unloaded inefficiency to 51 kW in the 2005/2006 season, and gave greater scope for supply-side improvements.

As a consequence of implementing the entire programme of operational and capital improvements, the improved control regime of the compressors is responsible for energy savings of 23 kW in Te Rapa CAS electrical demand (4 % savings).

VSD COMPRESSOR RESULTS IN IMPROVED SYSTEM PRESSURE CONTROL

Before the capital improvement project Te Rapa was running with low system pressures. This pressure was unsustainable during peak processing periods, especially with the introduction of the new packaging facility. After the new VSD installation, Te Rapa is operating within a pressure band which is narrower than before. The system pressure is at 6.5 barg[13] which provides suitable air flow delivery for the end usage of air. Electrical energy savings of 4% from the original power consumption rate have resulted (24 kW)[14].

FUTURE ENERGY EFFICIENCY IMPROVEMENTS AVAILABLE TO TE RAPA

There is an additional 4-5% energy savings which can be made by improving the compressor air intake. Currently air intake is being drawn in from the compressor room at 30°C+. Compressor performance is affected by the intake air temperature. By ducting the intake air from the outside will allow the compressor to operate more efficient, approximately (+ 5%) given the current temperature differences. High intake temperature will also affect dryer performance and the life of the electric motor (the maximum operating intake temperature for the compressors is 40°C).

4.5.2 Edgecumbe site

ENERGY EFFICIENCY GAINS AT EDGECUMBE RESULTING FROM THE CAPITAL PROJECT

Implementation of the efficiency programme completed at Edgecumbe started with the replacement of the turbo-compressor with a VSD machine in early November 2006. This enabled the flow to match against demand, which the large Turbo compressor could not do with its large flow. With the VSD installation, the total power consumed by the compressors dropped from an average of 353 kW to an average 294 kW. This is a recorded electrical demand saving of 59 kW.

The plot in Figure 4.3 shows compressor power before and after the project. The red line traces the electrical demand of the turbo compressor through to October 31. After that date, the red line is the representation of the VSD machine. The green line is the fixed speed compressor, the sum of these electrical demand profiles (green and red) combine to 294 kW.

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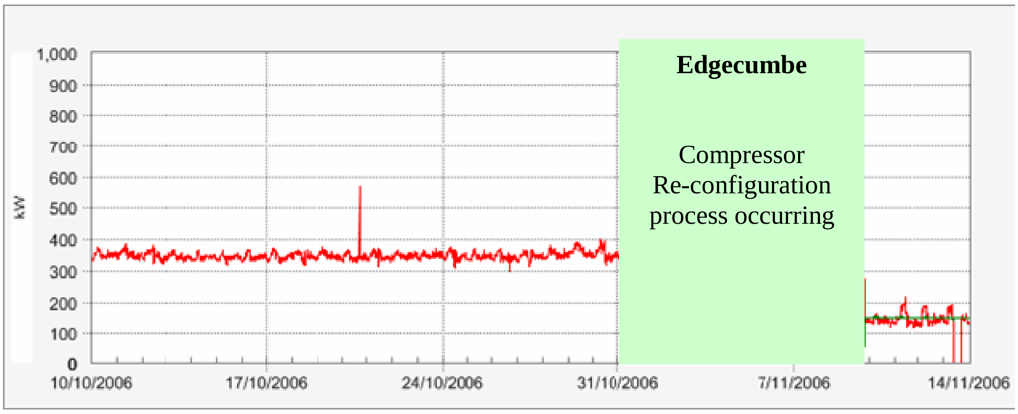
[13] See Appendix D.
[14] This has been discussed in detail earlier in Section 4.3.

Figure 4.3 Plot of the CAS electrical demand at Edgecumbe



FUTURE ENERGY EFFICIENCY IMPROVEMENTS AVAILABLE TO EDGECUMBE

The planned replacement of the large Turbo compressor has been carried out and a subsequent leak test completed. A total of 491 leaks have been identified[15]. These air leaks equate to an estimated flow loss of 676 m^3/hr or 23.8% of the generated air flow. With complete air leak rectification 70 kW of power savings would result.

Artificial demand removal will also take effect at Edgecumbe. One application in the milk processing plant uses compressed air to sparge (not agitate) a water tank has been modified to minimize air use. The site has planned to complete the modification to remove this inappropriate air use.

It is recognised that some air leak rectification has been completed (estimated at 50%). A reasonable estimate of the total future savings is 71 kW, derived from the following areas:

- from completing the air leak rectification (Te Rapa experience estimates this to contribute 75% of total flow losses)
- removal artificial demand (Te Rapa experience points to artificial demand representing 25% of total air loss)
- drop supply pressures (Pressure drop at Te Rapa contributed to 4.2% energy savings)

Table 4.21: Forecast electrical demand savings at Edgecumbe.

Future electrical demand savings yet to be achieved at Edgecumbe CAS		
Total available power savings with 23.8% flow reduction from current CAS demand (294 kW)	70	kW
Flow savings yet to be achieved through air leak management (50%)	35	kW
Demand savings available through artificial demand removal (25% of total flow loss)	23.3	kW
System pressure reduction (4.2% reduction in generation power 294 kW)	12.3	kW
The total amount of reduced electrical demand forecast for the Edgecumbe CAS	70.6	kW

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[15] Results of and air leak detection survey at Edgecumbe in March 2007.

4.5.3 Whareroa site

ENERGY EFFICIENCY GAINS AT WHAREROA RESULTING FROM THE CAPITAL PROJECT

The savings at Whareroa can not be quantified at this point. This site will remain a 'work in progress' until the Turbo compressor from Edgecumbe is installed. Indications are that this change will allow the site to operate on a single compressor (within its flow control range) providing a more efficient CAS with improved specific power performance. This installation will occur after the corrective actions of the leak detection programme, which is currently underway.

4.5.4 Energy savings across the Fonterra sites from the capital improvement project

The capital improvement project was expected to deliver 2.4 GWh of energy savings across the three Fonterra sites. This was based on the collective CAS electrical demand being reduced by 325 kW. At the time of this report writing 134 kW of reduction has been achieved across the Te Rapa and Edgecumbe sites. This level of savings will result in electricity consumption savings of 1.0 GWh per annum and is summarised in Table 4.22.

Table 4.22: Energy savings accrued to date

Fonterra Site	Projected demand savings (kW)[16]	Current level of CAS demand savings [17]		Achieved annual energy savings (GWh)
		(kW)	Source	
Te Rapa	65	51	Improved compressor control	0.38
		24	Reduced system pressure	0.18
Edgecumbe	150	59		0.44
Whareroa	110	-		-
Total Accrued	325	134		1.00

Table 4.23: Total energy savings forecast when project is completed

Fonterra Site	Projected demand savings (kW)[18]	Forecast CAS demand savings		Achieved annual energy savings (GWh)
		(kW)	Source	
Te Rapa		0	Essentially complete	0
Edgecumbe		71	Further air leaks mitigation	0.52
Whareroa		110	Project not yet started	0.81
Total Forecast		180		1.33
Total Accrued		134		1.00
Total Forecast	**325**	**314**	**Total expected across sites**	**2.33**

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[16] See projected electrical demand savings section 4.4.4.
[17] The savings at Te Rapa are a combination of 51 kW as a result of improved compressor control and 24kW as a result of lowering system pressures.
[18] See projected electrical demand savings section 4.4.4.

At Edgecumbe and Whareroa the capital improvement project and the subsequent CAS modifications had not been completed at the time of writing. The continuous improvements to the Fonterra CAS are expected to materialise savings as the plant alterations at Whareroa are completed and air-leak and artificial demand management is completed at Edgecumbe. Table 4.23 illustrates that these future improvements should yield a further 180 kW in demand reduction, equating to an energy savings of 1.33 GWh per annum.

In total the project is still on target to deliver 314 kW of demand reduction, or 2.3 GWh per annum, to Fonterra CAS. This compares highly favourably to the project target of 325 kW and 2.4 GWh per annum respectively.

4.6 Conclusions of the Fonterra case study

General approach to CAS energy efficiency:

- A compressed air champion has been appointed with a mandate to maintain the continuous improvement programme.

- Emphasis has been placed on the measurement of the energy performance of CAS. The establishment of ‘baseline data’ has been established to monitor improvements to energy efficiency from any planned activity. It is important to register the impacts of any changes to the CAS or the production process.

Fonterra – CAS operational improvements

- Frequent air leak detection and remediation, should be implemented as part of an on-going ‘good housekeeping’ improvement programme. Strict adherence to maintenance schedules are important to ensure efficient running conditions are maintained.

- A complete understanding of the demand-side was necessary as was the familiarisation of the patterns for the end uses of air. Engineering solutions can then implement to accommodate demand peaks.

- Air leak management has resulted in **18% energy savings** at Te Rapa. Notable progress has been made in leak detection and remediation methods. This includes the measurement of air volumetric flow rates and the reporting of air loss savings. These features are essential to effective air leak management.

- Continuous monitoring of CAS energy performance and the end use of the compressed air is necessary to avoid wastage. Removal of artificial air demand has resulted in **6% energy savings** at Te Rapa.

Fonterra - Capital improvement project

- This exercise has shown that fundamental engineering knowledge regarding the performance of existing CAS equipment and the demand for compressed air is critical before any new capital (Supply side equipment), like new air compressors, can be specified in a robust way. Consideration to the future requirements of the CAS should also be allowed for.

- In the case of Te Rapa the introduction of a variable speed drive compressor has allowed a further reduction in **system pressure** (4% savings) and has eliminated the **‘unloaded’ compressor running time** (4% savings). The VSD compressor has provided **8% energy savings** in total.

- The capital project in not fully implemented. Edgecumbe site has achieved 59 kW of electrical demand reduction (**17% energy savings**). Future energy savings at Edgecumbe will result from the reducing air demand and system pressure (71 kW).

- The Whareroa CAS re-configuration remains a work in progress.

4.7 Lessons learned from the Fonterra case study

A number of important 'lessons learned' have come out of this early pilot project work. The factors that led to success at Te Rapa are detailed below.

4.7.1 Identified barriers to CAS energy efficiency improvement

The work over the last 3 years with Fonterra has provided solutions to the barriers that constrain improvement of energy efficiency in CAS. The project team encountered the following barriers during the Fonterra case study:

1. Ensuring savings are sustainable is an ongoing issue.

2. Lack of CAS knowledge has hampered achievement of CAS energy efficiency.

3. Commercial drivers for capital investment are tight when based solely on energy savings.

4. Implementation of metering requirements was a low priority for management.

4.7.2 Suggested order of operations for sites wanting to improve CAS efficiency

The pilot project team suggests that the following order of activities will improve the likelihood of sustainable energy savings:

1. **Metering -** Collect data on power (kWh) and air flow (m^3/h) meters to establish a baseline level of performance in CAS. This is an essential first step and is vital for a complete understanding of the situation. Without establishing the original performance of the CAS, it is impossible to quantify the impact of any improvements in energy efficiency.

2. **Air leak management -** Carry out regular leak tests on the compressed air system and repair all major leaks as a matter of priority. We have seen at Fonterra that over half of the energy savings have been achieved through the elimination of air leaks. This is a logical place to begin an energy efficiency improvement regime.

3. **Peak air demand -** Analyse the real-time data (if available) on factors that create the peak air demands and gain understanding of the production requirements. CAS is designed to cope with peak loads. Peak demands set the generation requirements: by removing the demand for air, generation requirements are reduced.

4. **Pressure settings** – Reducing the pressure set points is a valuable supply-side improvement for energy saving. When peaks in demand and unnecessary drops in pressure (piping re-sizing) are removed from the system improved control strategies can be introduced.

5. **Air compressor optimisation -** Installed compressors can be correctly assessed after the above actions have been completed. Purchasing new equipment is avoided when several techniques which revolve around the optimal sequencing of compressor loading and start-up are used to match demand for air.

4.7.3 A successful air leak management programme

Air leak detection is paramount to air leak management. Ultrasonic leak detection has proved to be most effective for leak detection. The Te Rapa site has encouraged the use of professional ultrasonic leak detection services. They now treat an air leak audit as a routine exercise and ensure that all the leaks are repaired as a priority. This is an important strategy for getting on top of the huge number of leaks which can become overwhelming for a maintenance department.

Table 4.24: The results from the ultrasonic leak detection surveys conducted at Te Rapa

Date	Audit size	Total detected leaks	Urgent leaks detected	Leaks repaired on spot	Estimated flow losses m^3/h
October-2004	Full	361	0	0	1,082
August-2005	Full	391	83	95	1,300
June-2006	Partial	287	79	187	250

The progress with the air leak detection surveys at Te Rapa

The required frequency of undertaking leak audits will vary from industry-to-industry depending on the operational and seasonal demands. The Te Rapa experience is pointing towards 3 annual leak audits on milk processing sites:

1. before the winter shut-down to identify the difficult leaks to be fixed when the plant is down;
2. after the winter shut-down;
3. during peak season.

Building a site database about the leaks and the tags were important elements of best practice at Te Rapa. This ensures the leaks are fixed and helps identify and simplify future leak surveys. If this undertaking is maintained, leak audits may be reduced in duration from 5-day exercises on large sites to 2-to-3 day audits.

Table 4.25: Improving the outcomes of air leak detection services

Year	Survey	Key features	Remediation
2004	Descriptive summary	Basic Information. Data entered manually. Assumptions to correlate dB readings with air flow.	Leaks repaired after survey.
2005	Excel Data Base	Database approach allowed easy access. Same assumptions to quantify losses.	Leaks started to be repaired on the spot.
2006	Full database approach	Allows data to be filtered and sorted. Improved modelling of air leak losses. Generic fault codes added.	More leaks repaired during survey.

5. METERING AND REPORTING OF INDUSTRIAL CAS ENERGY PERFORMANCE

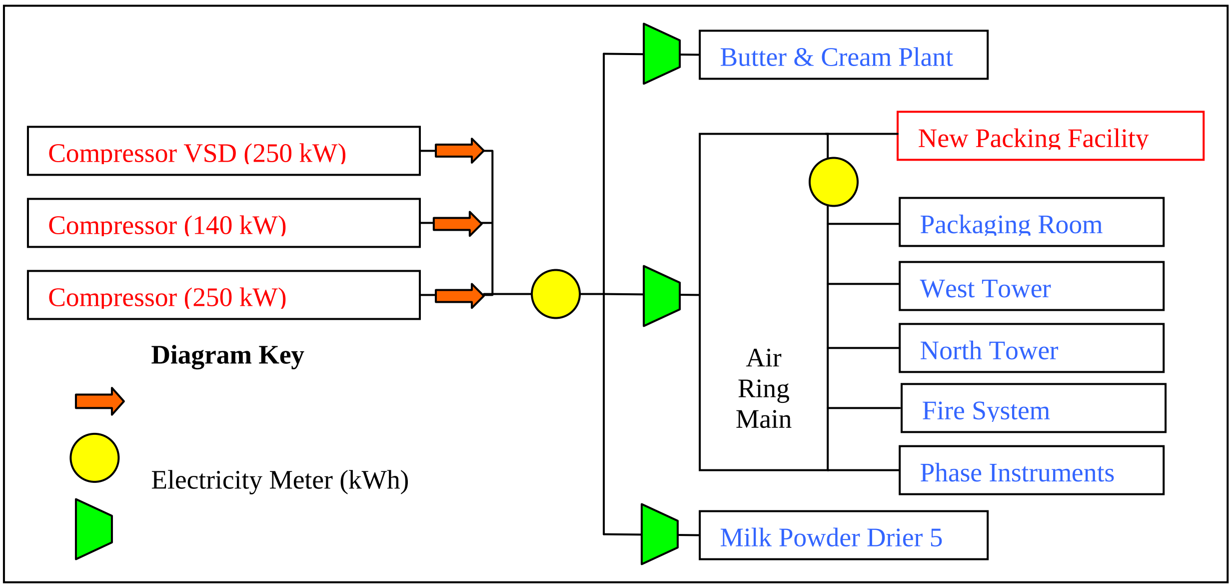
Robust and accurate metering and reporting functionality is vital first step for complete understanding of the CAS performance. Without establishing the original performance of the CAS, it is impossible to quantify the impact of any improvements in energy efficiency. Operational decision making for intended energy savings projects becomes more scientific. Metering and reporting at high standards ultimately provides for more accurate financial accounting and capital expenditure planning

Most industrial sites have limited compressed air system instrumentation, relying on compressor pressure gauges and other instrumentation associated with the manufacturing process. Energy consumption information for CAS is often restricted to electrical current drawn by the compressor motor. There is seldom facility to measure compressed air flows. Te Rapa was no exception.

5.1 Metering of CAS energy performance at Te Rapa

Over the pilot project period, 2004 until 2007, electrical metering of the of the air compressors at Te Rapa has been completed through temporary measures. Air flow monitoring has been achieved in isolation, but no longitudinal study exists. Recently, in 2007 installation of air flow meters and permanent electrical metering have been calibrated and commissioned.

Figure 5.1: Schematic of the CAS metering currently installed at Te Rapa



5.2 Reporting on CAS energy performance

As part of their ERP programme, Fonterra adopted a comprehensive monitoring and targeting (M&T) regime[19] to focus on gathering appropriate plant performance data sets from meters to gain a more comprehensive understanding of system energy performance.

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[19] See Appendix E.

The CAS M&T reporting evolved over the course of the pilot project and has been restricted by the available metering data[20]. The installation of permanent metering has enabled the critical elements for effective CAS performance to be captured and analysed. The reporting provides a more complete picture of CAS performance and is being issued weekly to Fonterra staff[21].

M&T reporting provides the platform for CAS energy performance analysis and comparison. Developing a regime for measurement and display of these parameters is a key out come of this pilot project. The reporting methodology completed at Te Rapa, can be extended out to other Fonterra sites, with minimal cost and time. Only slight tailoring of the M&T report, to accommodate each individual site's processes and compressor configuration is necessary. This development work will also enable effective CAS M&T to be rapidly instituted elsewhere in industry.

As a result of the reporting function, KPIs for CAS energy efficiency performance from this pilot were identified. Each KPI is discussed in greater detail on the following page.

1. Compressor utilisation. **(% load)**

2. The specific power use for the compressors. **(kW/[m^3/min])**

3. The overall supply pressure. **(barg)**

4. Total electricity use of the compressors. **(kWh)**

5. Total compressed air use. **(m^3/h)**

Compressor utilisation

The first stage of the reporting at Te Rapa focussed on the compressor utilisation using the electricity data from the temporary metering. This ensured that the stand-by compressors were not run unnecessarily in the unloaded position. The development of this reporting has been restricted by the metering available on site. The M&T report has been developed through a series of versions.

Specific power performance analysis

The specific power is probably the most important KPI for the supply side of CAS. It is a valuable indication of performance because it represents the efficiency at which the compressors are supplying the demand for compressed air. The units for specific power are (kW) use per air flow (m^3/min). The specific power performance has been given priority in the developed M&T report. The initial target was set at 6.5kW/(m^3/min) for the compressor mix at Te Rapa. Te Rapa has made progress in the performance of their specific power.

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[20] See Appendix F (Version 1)
[21] See Appendix F (Version 2)

Overall supply pressures

Supply pressures are an analogous indicator of CAS energy performance. Pressure gauges are, easy to install, accurate and reliable. When multiple compressors exist within an installation, compressor set points control the timing of each compressor’s load cycle. When system pressure drops due to demand within the CAS, a compressor will start the compression cycle to maintain the necessary air flow. The compressor pressure set points are governed by the demands of the manufacturing process. Pressure losses in the air net, result in set pressures being higher than the process requirement this is typically between 0.5 – 1 barg.

Total electricity usage

Reduced electricity consumption is the net benefit of energy efficiency improvements for CAS. Reduced energy consumption reduces operating costs for the manufacturer. Total electricity use once quantified and adjusted for production variance through bench marking procedures enables accurate comparisons for energy performance for the CAS. This is of can be a benefit to operational and management staff.

Total compressed air usage

Generally, there is lack of accurate metering of air flow in industry. Air flow metering is vulnerable to errors through improper configuration and calibration. Monitoring of air flow means that changes in manufacturing techniques and or changes to the plant can be quantified in respect to their impact on CAS performance. Historical review of air flow usage can also highlight the collective losses through air leaks throughout the CAS distribution system.

6. EXPANDING UPON THE FONTERRA CASE STUDY TO ITS WIDER APPLICATION FOR NEW ZEALAND INDUSTRY

6.1 Building further upon international experience

Experience in the introduction of a “best practice” programmes for compressed air systems exists already. Many international programmes were reviewed during this pilot project[22].

1. The Compressed Air Challenge - US Department of Energy [23].

2. Compressed air systems in the European Union- European Commission **SAVE** project. (**S**pecific **A**ctions for **V**igorous **E**nergy Efficiency). Built upon the large audit programme carried out in Germany[24] .

3. Energy Efficiency best practice Programme - now administered by The Carbon Trust, formerly the UK Energy Efficiency Office[25].

The findings from these programmes can be summarised as:

1. Best practice programme goals include:

- Development of standards and specifications for energy efficiency.
- Promotion of training and awareness for the efficient use of energy.
- Development of financial techniques to promote and encourage investment in energy efficiency (e.g. Third party financing).

2. Most important energy savings were achieved through:

- reducing air leaks;
- better system design;
- use of VSD compressors;
- Recovery of waste heat.

3. Issues encountered in realising energy savings included:

- A general lack of awareness of potential energy savings from CAS. This lack of awareness is evident from site operations staff to those at a senior management level.
- Highly effective and simple housekeeping measures were often over looked (ventilation and reducing air leaks).

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[22] See Appendix G
[23] See Reference No. 4
[24] See Reference No. 5 and 6.
[25] See Reference No. 7 and 8.

- Emphasis on the initial capital cost for new compressor installations, rather than full life cycle cost analysis.
- A general absence of compressed air cost accounting.

4. Recommended solutions to the identified issues in CAS efficiency

Table 6.1: Recommended solutions to the identified issues in CAS efficiency

Issue	Solution
Lack of awareness of energy efficiency issues	• Launch awareness and advertising campaign • Produce data and fact sheets
Slow adoption of new technologies	• Demonstrate innovative solutions • Create awards for superior design
In-ability to sustain long term energy savings	• Provide encouragement for installation of measurement equipment • Communicating success through training and education
Poor understanding of CAS economics	• Present life cycle cost analysis • Environmental considerations also provide economic benefit
Knowledge imbalance within the marketplace	• Improve labelling and certification of systems • Providing guidelines for improving contracts • Encourage agreements between suppliers and end users.
Differing outcomes of best practice programmes	• Taxes, subsidies and regulations required at different levels to ensure actions are adopted.

6.2 Pilot study investigation into sample group of CAS in Hamilton

The next phase of the pilot project was to expand the Fonterra case study to a random selection of manufacturing sites in the Waikato Region. The aim was to assess the CAS at ten (10) manufacturing sites with a view to establish the standard of compressed air systems that was typical of the Fonterra pilot and world-wide experience.

This element of this pilot project was to conduct “walk-through assessments” at each of the sites. Walk through assessments are simple inspections using personnel experienced in CAS to identify opportunities and scope for subsequent energy efficiency improvements. This approach is well established in other international programme methodologies and consists of identification of opportunities against established templates to evaluate both the supply and demand side of CAS. Integral to the walk-through assessment process is consultation with managers and operators to establish operating practices and production constraints.

6.2.1 Size of sample sites and their CAS

The sites were randomly selected from the meat, plastics, canning and boat building industries with a range of CAS varying in size from very small to medium. The businesses were selected as a random representation of the industrial users of compressed air in Hamilton.

The following table is used to describe the relative CAS size of the visited Hamilton sites.

Table 6.2: Size of CAS installations at various Hamilton sites visited

Category	Installed CAS site demand (kW)	Number of sites visited in each category
1	>1,500	0
2	1,000 - 1,500	0
3	500 – 1,000	1
4	75 - 500	4
5	25 - 75	3
6	<25	2

The randomly selected sites are over represented in the site sizes at the smaller end of the spectrum.

Table 6.3: Size of CAS installations at various Hamilton sites visited

Company	Site size by category	Industry	Compressed air system (kW)
A	3	Plastics manufacture	690
B	4	Cans manufacture	455
C	4	Electronics	130
D	4	Meat processing	120
E	4	Plastics manufacture	80
F	5	Meat processing	60
G	5	Plastics manufacture	30
H	5	Air craft manufacture	30
I	6	Boat building	22
J	6	Tyre repairs	11
Total			1,598

6.2.2 Energy savings potential identified through the pilot study assessments

The walk-through assessments were completed with the objective of gaining insights into local site conditions and knowledge of CAS. These were not full CAS audits, but rather simple observations made by experience personnel with an extensive background in compressed air system design and operation. It is important to note that energy loss through air leakage was significant at some sites, but not quantified through time constraint. For the sake of expediency it was assumed that an average of 10% energy was being lost through air leakage.

Table 6.4: Potential electrical savings at various Hamilton sites visited

Company	Installed capacity (kW)	General comments	Potential savings (%)	Air leakage (%)	Total energy savings (%)	Electrical demand savings (kW)
A	690	Compressor selection mix not ideal	5	10	15.0	104
B	455	Good installation	2.5	10	12.5	57
C	130	Good installation	-	10	10.0	13
D	120	Site conditions interfered	-	10	10.0	12
E	80	Savings potential	11	10	21.0	17
F	60	Good installation, New VSD	-	10	10.0	6
G	30	Savings potential	11	10	21.0	6
H	30	Declined full involvement	-	10	10.0	3
I	22	Small energy savings	7	10	17.0	4
J	11	National campaign potential	7	10	17.0	2
Total	1628	Target sites more selectively				224

Table 6.5: Potential electrical savings at various Hamilton sites visited

Company	Installed capacity (kW)	Electrical demand potential savings (kW)	Annual operating hours	Energy savings (MWh)
A	690	104	7500	776
B	455	57	7500	427
C	130	13	6000	78
D	120	12	6000	72
E	80	17	5000	84
F	60	6	5000	30
G	30	6	4000	25
H	30	3	2500	8
I	22	4	2500	9
J	11	2	2500	5
Total	1,628	224	-	1,514

The sample size (10) was also small providing a skewed weighting for small sites, where large energy savings are unlikely. Therefore, the savings potentials are conservative and under represent the full opportunities amongst industry. Through 'best practice', operational improvements the collective reduction of CAS electrical demand over the 10 sites were assessed to be 224 kW.

Energy savings at the sites varies due to the range of operating conditions. The collective energy savings through each site achieving their identified savings potential is 1.5 GWh.

6.2.3 The energy savings potential for CAS in New Zealand

In CAS supplier terminology there is a step change in compressor sizing when the electrical demand of a compressor motor exceeds 75 kW. This motor size of 75 kW provides a natural splitting point for the market for air compressors into two sub segments (Mass and Industrial)

Manufacturing sites that have installed generation capacity in excess of 75 kW, are regarded as being the **Industrial Market.** Enterprises ranging in installed compressor capacity between 0-75 kW are regarded as representing the **Mass Market.**

Table 6.6: Industrial market CAS savings

Pilot project sites with installed CAS capacity representative of the industrial market of CAS			
Company	Installed capacity (kW)	Total savings %	kW
A	690	15	103.5
B	455	13	56.9
C	130	10	13.0
D	120	10	12.0
E	80	21	16.8
Average savings potential in CAS across the sites		13.8	%
Total electrical demand savings available across the sample		202.2	kW
Number of sites visited from the industrial market		5	
Average electrical demand savings available per site		40.4	kW
Annual energy savings based on 6,500 operational hours		262.6	MWh

Table 6.7: Mass market CAS savings

Pilot project sites with installed CAS capacity representative of the mass market of CAS			
Company	Installed capacity (kW)	Total savings %	(kW)
F	60	10	6.0
G	30	21	6.3
H	30	10	3.0
I	22	17	3.7
J	11	17	1.9
Average savings potential in CAS across the sites		15.0	%
Total electrical demand savings available across the sample		20.9	kW
Number of sites visited from the industrial market		5	
Average electrical demand savings available per site		4.2	kW
Annual energy savings based on 2,500 operational hours		10.5	MWh

INDUSTRIAL MARKET SEGMENT– SAVINGS POTENTIAL

Based upon the pilot study sample group (and Fonterra Te Rapa), if all the sites achieved the operational improvements that would result from bringing their sites to a best practice standard, 40 kW of electrical demand will be removed from the CAS consumption per site. This corresponds to energy savings of 263 MWh per annum.

MASS MARKET SEGMENT – SAVINGS POTENTIAL

Based upon the pilot study sample group, if the sites achieved the operational improvements resulting from best practice, on average 4 kW of electrical demand will be removed from the CAS consumption. This corresponds to 10 MWh of reduced electricity consumption over a year.

6.2.4 Achieving energy savings effectively at a national level

Operational improvements at the visited sites would lead to energy savings of 15%. This is a conservative estimate of the full potential, and less than what has been achieved at Fonterra Te Rapa. During this pilot project, we found the average energy savings in the mass market sites to be 10 MWh per annum. In the industrial market the energy savings potential is 263 MWh per annum.

This means that on average 26 sites from the mass market would need to be brought up to best practice standards to achieve the same level of energy savings of one site from the industrial market. It is not feasible to visit every CAS installation in New Zealand. Sites from the mass market require a different strategy for achieving best practice operation improvements than those from the industrial market.

6.2.5 Non energy specific benefits from CAS improvement

Improvements in productivity and reduced maintenance cost are not specific to energy efficiency, but provide benefit for businesses. Some examples from the sites in Hamilton include:

Improved productivity

- Consistent pressure and flow improve capital machinery performance
- Reduction of machine downtime

Improved tool life and reduced maintenance costs through better condensate management

- Reduces tool damage (maintenance cost)
- Reduces pipe corrosion (resistance to flow results in pressure drops)
- Compressor damage due to water ingress (maintenance cost)
- Prevents oil and water contaminants reaching storm water drains

Improved production performance through better air distribution (increased air storage -receivers)

- Smoothes out pressure variance (production effects)
- Provided a buffer for peak air demands (production effects)
- Helps with condensate removal (maintenance cost)

6.2.6 CAS supplier service and performance

Supplier performance throughout the visits also varied. The appropriateness of CAS components and their relative positioning at some sites was exemplary whilst at other sites was poor. A lack of after-market service levels was apparent in some instances. Some sites reported struggling to achieve acceptable levels of service standards from their providers. This provides a significant feature to be addressed in any future best practice programmes.

6.2.7 Conclusions of the pilot study of the Hamilton sites

Based on our pilot study of the 10 sites in the Waikato Region, we can conclude the following:

- The ‘walk through assessment” were effective in assessing energy consumption patterns. Full energy auditing would have been inappropriate at this time given the size of the companies involved and the current condition of their plants.

- Several of the sites we visited were either too small or too well installed to be able to realise any significant energy savings. A larger sample size, with more sites with CAS installations in medium to major size categories would likely identify larger savings opportunity.

- There was a wide variation in several aspects relating to CAS energy efficiency in the sites visited. There is variation in; installation standards; maintenance levels and supplier performance (equipment, and service).

- Smaller sites (30kW or less) still have savings potential, through changes in end use and in system pipe work. It is envisaged that generic communication publications could address this section of the market.

- Larger sites or (75kW and above) provide the most potential for energy savings. Compressors are often running in 24/7 operations. Larger sites also have the in-house resources, or service providers to carry out recommendations.

- Site actions to date have not always achieved the full savings potential. Several sites are already achieving a degree of best practice and will have little opportunity for further energy savings, this is encouraging.

- The feedback from industry is that manufacturers are looking for assistance and to wiling participate in CAS energy efficiency.

- Management on site needs to be involved and prepared to drive initiatives on site.

- System pressure reduction, removal of inappropriate compressed air uses and reducing unloaded compressor function can provide energy savings with minimum investment cost. These could be considered part of continuous improvement.

- The key benefits to sites achieving best practice standards in CAS include: reduced energy costs, improved plant reliability, increased capital machinery productivity and elevated environmental standard conformance.

6.3 Why additional energy savings can be achieved nationally

Te Rapa can be considered a case study to illustrate the progress that can be made in operational improvements with continued focus. Valuable experience has come out of this work which can be used to confirm the need for a programme for achieving similar electricity savings on a national basis.

More comprehensive audits on the sites with compressed air systems sized 75kW and above should follow. It is anticipated that electricity savings will be identified in line with the international average between 15% and 40%.

We have learnt from this pilot project, that it is impractical to choose sites at random due to the low energy savings potential of small sites (below 75 kW). Future successful activity will involve selecting potential participants by the following criteria:

- Select large electricity consumers from industry
- Sites with installed compressor capacity of 75kW and above
- Senior management who are motivated to drive site participation

6.3.1 General comments from industry on the potential of a CAS best practice programme

The term “best practice” is becoming more accepted by New Zealand industry as companies seek continuous improvements to keep up in a global market place (World best practice). This is often more evident in manufacturing techniques and practices, than just in energy or energy efficiency, although these initiatives drivers can go hand-in-hand.

There was good support from senior management from the visited companies. Senior management’s commitment and involvement is critical to the success of such a programme.

Feedback from the sample group was very positive towards the “CAS best practice” concept. Support is expected to come from a number of national organisations which see the improvement of New Zealand’s efficiency of energy usage.

The wider goals of a best practice programme are to raise the whole overall standards for the engineering design, operation and maintenance of CAS. Improvements both in productivity, through loss of downtime and reduced maintenance costs would result.

Support for such a best practice programme is also consistent with the objectives of “Engineering a National Energy Strategy” and the IPENZ Energy Policy [26]. Improving New Zealand’s efficiency of energy usage, to match global best practices for similar economies is seen as a key long-term goal, which Government actions should contribute to.

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[26] See Reference No. 9.

6.3.2 Confirmation of the barriers to investment and CAS efficiency

The obstacles to investment and CAS efficiency in the international programmes were also identified domestically in New Zealand. These can be consolidated to:

1. Lack of awareness and technical knowledge of CAS performance

2. Emphasis on supply side (capital expenditure) alternatives for energy savings at the expense of demand side (practical improvements)

3. Inadequate prioritization for CAS performance management

4. Poor strategy for improvements in energy efficiency at a site level and on a national scale

1. LACK OF AWARENESS FOR CAS ENERGY EFFICIENCY

Amongst industry there is generally a poor awareness of the energy savings potential. This lack of industry knowledge has hampered CAS energy efficiency capability and is evident from site operations staff to those at a senior management level. Presently, there is very little publicly available material to help companies with energy awareness, training, and recommended performance standards.

2. CAS EFFICIENCY IMPROVEMENTS ARE FOCUSED ON SUPPLY SIDE ALTERNATIVES.

The CAS industry is mostly driven by supply-side equipment and service providers. Often highly effective operational improvements exist. Some examples of simple housekeeping measures include reducing air leakage and reducing unnecessary air use. These more cost effective solutions are often over looked.

When new supply side equipment is required there is an over emphasis on minimisation of the initial capital cost outlay. But a full life cycle cost analysis of a compressor identifies energy consumption as contributing 75% of the cost.

3. INADEQUATE CAS PERFORMANCE MANAGEMENT

Gaining sustainability in the achievement of energy savings is an ongoing issue. Implementation of metering requirements is a low priority for management, this is indicative of the priority that management places on CAS performance. Measurement of compressed air systems performance is essential to quantifying the affect of energy efficiency improvements, but is seldom evident.

4. LACK OF STRATEGY FOR REALISING CAS ENERGY SAVINGS.

Through the observation factors including; limited technical awareness, poor prioritization in the implementation of available energy savings initiatives and a general absence of compressed air accounting and monitoring, it becomes clear that there is a lack of strategy for the realisation of energy savings in industry. This lack of internal strategy occurs at an individual site level where there is little emphasis to improve the ‘total system’ performance. Correspondingly there is no evidence of an effective national strategy for making energy savings.

7. THE GENERAL CASE FOR BEST PRACTICE IN CAS ENERGY EFFICIENCY

7.1 Elements that enable a successful best practice programme for CAS in New Zealand

This pilot project confirms that introducing a regime of “best practice” for CAS in NZ will realise significant energy savings. The barriers to the uptake of such an initiative have been clearly identified and can be managed accordingly. A coordinated and strategic approach will see the results achieved. Most of the elements of a best practice programme are straightforward and could be rolled out successfully in New Zealand.

A best practice programme should help to transform the market with technical and engineering support. As a result of this pilot project that there is a reasonable expectation that such a best practice programme should:

Promote and develop awareness of CAS energy efficiency

- Provide a foundation for transforming the energy efficiency up-take by tackling the barrier of poor awareness of the energy savings potential.

- Developing relevant information and training material to support the programme for the mass market of CAS users. It is more cost effective to target the mass market with an advertising campaign.

Focus CAS efficiency improvements on the total CAS system

- Developing the appropriate minimum standards for performance to “best practice” with both the equipment suppliers and end-users.

- Promote that global experience has shown that significant energy savings can be achieved through cost effective practical improvements. This is supported by the individual case study at Fonterra.

Help site management improve CAS performance

- It would consist of promoting continuous improvement in the operation and maintenance, with a strong focus on measurement and the analysis of sustainable energy savings.

- High emphasis on measuring and encouraging the sites with largest CAS capacity install the necessary metering and reporting. Part of a future accreditation process could be the reporting of compulsory information on the energy performance of large CAS systems.

Implement a strategy for realising CAS energy savings

- Target delivering a minimum of 20% electricity savings from industrial CAS through best practice.
- 32% electricity savings have been achieved at Te Rapa, this is in line with international expectations. 15% energy savings were estimated across the sample sites in Hamilton. This value is considered to be conservative and under representative of the full potential in New Zealand industry.
- Initially focus on industrial sites that have installed CAS capacity above 75kW. They would be targeted through visits and workshops to engage key people to take action.

7.2 Market size for CAS energy efficiency in New Zealand

The market size for CAS has been estimated by undertaking a targeted market research of the largest 150 industrial sites. This data, along with experience from the pilot project and knowledge from the pilot project team was used to put these results together.

Table 7.1: CAS market size

Category	Number of sites	Installed CAS site demand (kW)	Average CAS site demand (kW)	Annual run times (hours)	Collective electrical demand (MW)	Collective electricity use (GWh/y)
Industrial market (>75 kW)						
1	5	>1,500	3,000	8,000	15	120
2	15	1,000 - 1,500	1200	8,000	18	144
3	100	500 – 1,000	750	6,000	75	450
4	380	75 - 500	150	6,000	57	342
Sub Total	500				165	1,056
Mass market (<75 kW)						
5	1,000	25 - 75	50	4,000	50	200
6	5,000	<25	10	3,000	50	150
Sub Total	6,000				100	350
Total	6,500				265	1,406

The electricity consumption of CAS in New Zealand

These estimates combine to project the total CAS market to consume 1,400 GWh of electricity every year. The CAS market, from a best practice roll-out perspective can be divided into two segments; the industrial market and mass market. The split in the market occurs when the electrical demand for the compressors is at 75kW. Both these market segments should be approached with customised strategies to achieve the energy savings.

1. Industrial market with CAS capacity above 75kW capacity involves 500 sites;

   Industrial market - CAS consume at least 1,056 GWh/y.

2. Mass market with CAS capacity below 75kW constitutes 6000 sites;

   Mass market - CAS consume at least 350 GWh/y.

7.3 A CAS best practice programme could realise these potential savings

The potential for national savings can be estimated from this market size. A national target for electricity savings is required that is both ambitious, yet achievable and fits with the New Zealand Energy Efficiency and Conservation Strategy (NZEECS)[27].

It is the experience of this pilot project that up to 32% energy savings can be readily achieved through best practice methodology. International studies suggest that up to 40% savings are achievable.

Using a dual approach the transforming New Zealand CAS into energy efficient performance the table below illustrated the potential energy savings on a macro scale. The pilot project has proved that operational improvements can readily achieve 24% electricity savings in CAS. Just through providing awareness to management on smaller sites within the mass market would allow for savings of up to 10%.

Table 7.2: Best practice programme targeted electrical savings

Market	Best practice programme	Targeted electricity savings (%)
Industrial market (75 kW +)	“best practice” - operational and capital improvements	15-40%
Mass market (< 75KW)	“best practice” – awareness campaign.	5-15%

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[27] See Reference No. 10

7.3.1 The industrial market for CAS

Energy savings of 20% can be practically achieved across the industrial market. This can be done by bringing the industrials site up to "best practice" through operational improvements. It is possible for efficiency gains over 20% to be achieved; however this may require capital investment projects which offer less cost effectiveness.

The best way to install best practice would be to implement individual site assessments. A top down approach of prioritizing the largest sites first would deliver the fastest impact. The industrial market is calculated to be consuming 1,056 GWh annually. Projected energy savings from a best practice programme, at 20%, equals **211 GWh per annum.**

7.3.2 The mass market for CAS

Introducing 'best practice' to the mass market (i.e. those sites with <75kW of CAS) has the potential to deliver **10% energy savings.** A more realistic target is considered to 10% saving rather than the 15% potential identified through the Waikato experience. Because an awareness campaign is more generic and not tailored to individual sites, it is unlikely that the full energy savings potential will be realised as not all sites will be compelled to adopt CAS best practice.

As these sites are smaller and numerous, a targeted campaign to individual sites would be expensive and time-consuming. An awareness campaign on CAS best practice would provide a more cost effective delivery method[28]. The mass market is calculated to be consuming 350GWh per year. Therefore, an energy awareness campaign to the smaller users is expected to deliver **35 GWh per annum** at 10% savings.

7.3.3 Potential energy savings of a CAS best practice programme in New Zealand

Overall, the full realisable potential of energy savings as a result of a CAS best practice Programme across New Zealand industry is estimated at **240 - 250 GWh per year** (211 + 35 = 246).

7.4 The next steps in the development of a best practice programme

Intervention at a national level will help to provide for a faster uptake in electricity savings. Without a national best practice programme, it will only be the large energy users, like Fonterra, that will make progress. Small to medium sized CAS will only make limited progress and savings from the mass market of very small CAS will be almost non-existent. Only a fraction of the potential gains from CAS at a national level will ever be realised.

The next stage in understanding the national benefits should be on a more vigorous economic basis. Such an exercise should take into some of the multiple benefits in starting an industrial programme with a compressed air systems "best practice" roll-out. It was outside the scope of the pilot project to provide a full cost benefit analysis of a best practice programme.

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[28] See Appendix G.

8. CONCLUSIONS

The conclusions of the Demand Response Limited pilot project into compressed air systems electricity efficiency for the Commission are:

1. Improvements to the Fonterra CAS at Te Rapa over the last 3 years have resulted in **32% electrical energy savings.**

2. Energy savings through **operational improvements** at Fonterra include:

   - Air leak management (18%)

   - Shedding peak air demands and inappropriate air use (6%)

3. Energy savings resulting from the **capital improvement** project at Fonterra include:

   - Reduction of CAS operating system pressures (4%)

   - Improved compressor loading and control (4%)

4. The projected energy savings (2.4 GWh pa) resulting from the capital project cannot be confirmed at this time as the remaining work is yet to be completed, however re-forecasting against accrued savings indicates that 2.3 GWh pa remains a realistic target. To date, the compressor reconfiguration project has delivered 1 GWh of annual electricity savings:

   - **Te Rapa:** 75 kW of electrical demand savings, per annum this equates to electricity savings of 0.56 GWh.

   - **Edgecumbe:** 59 kW of electrical demand savings, per annum this equates to electricity savings of 0.44 GWh. Work to reduce electrical demand is ongoing.

   - **Whareroa:** Compressor reconfiguration at this site is ongoing.

5. Robust metering and reporting of CAS performance is essential for sustained energy savings.

6. Successful energy management involves the metering and reporting of the following KPIs.

   - Compressor utilisation (Load/Unload [%])

   - Specific power performance (kW/[m^3/min])

   - Overall supply pressure (barg)

   - Total electricity use (kWh)

   - Total compressed air use (m^3/h)

7. The Fonterra experience of significant savings could be applied over a larger sample of industries.

8. There is potential for 15% energy savings at the 10 Waikato businesses assessed.

9. An opportunity exists in New Zealand for an energy efficiency programme for CAS. The findings of the pilot project confirm the energy savings potential of international programmes **(energy savings between 15-40%).**

10. Based upon the evidence gathered from the local and international experience there are four specific barriers to the adoption of energy efficient practice:

    - Lack of awareness for CAS energy efficiency
    - CAS efficiency improvements are focused on supply side alternatives.
    - Inadequate CAS performance management
    - Lack of strategy for realising CAS energy savings

11. The potential for energy efficiency savings in CAS across New Zealand industry is **250 GWh per annum.**

12. A CAS best practice programme should be coordinated at a national level. The programme could build upon the international models. By adhering to the lessons learned implementation times and cost would be reduced.

13. A dual approach is suggested to the two market segments of CAS.

    - **Industrial market** (Installed compressor capacity > 75kW). Target 20% savings by bringing individual sites up to 'best practice' standard.
    - **Mass market** (Installed compressor capacity <75kW). Target 10% savings through an awareness and information campaign.

9. RECOMMENDATIONS

The pilot project team can offer these recommendations regarding electrical efficiency in CAS.

Recommendations for energy efficiency improvements for Fonterra CAS:

Te Rapa

1. Maintain continuous improvement drive towards CAS energy efficiency
2. Continue with the air leak management programme
3. Control all in appropriate usage of compressed air
4. Improve ventilation of compressor housing so that air intake temperatures are minimised
5. Relay the priority of installing CAS metering to other Fonterra sites

Edgecumbe

1. Implement an optimal compressor control regime
2. Continue with current air leak management regime
3. Reduce the systems pressures

Whareroa

1. Complete the compressor reconfiguration project
2. Install necessary metering (electricity and air flow)

General recommendation of the pilot project:

1. Implement a national best practice programme for CAS electricity efficiency
2. Adopt a two tiered national best practice programme for CAS. Programme to specifically target the two market segments; the Mass market and the Industrial market.

References

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2. Electricity Commission, “Electricity energy efficiency”, www.electricitycommission.govt.nz.
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4. Compressed air challenge, www.compressedairchallenge.org.
5. P Radgen and E Blaustein, Fraunhofer Institute for Systems and Innovation Research, “Compressed Air System in the European Union - Energy, Emissions, Savings Potential and Policy Actions”, http://www.isi.fhg.de/publ/downloads/isi01b04/compressed-air-long.pdf.
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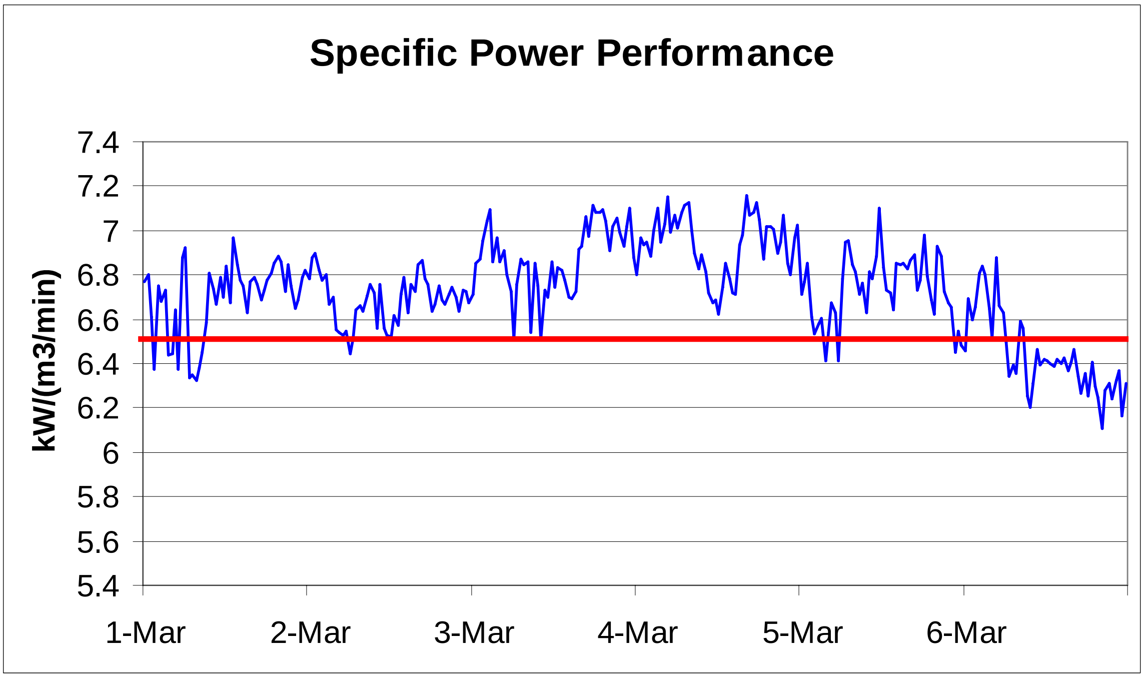
7. Energy Efficiency best practice Programme, www.thecarbontrust.co.uk/energy.
8. Energy Efficiency Office, “Compressed Air Costs”, Good Practice Guide 126, 1994.
9. IPENZ, “Engineering a National Energy Strategy - Energy Policy” - draft document 2005/2006.
10. Ministry of Economic Development, “Draft New Zealand Energy Efficiency and Conservation Strategy”, December 2006.

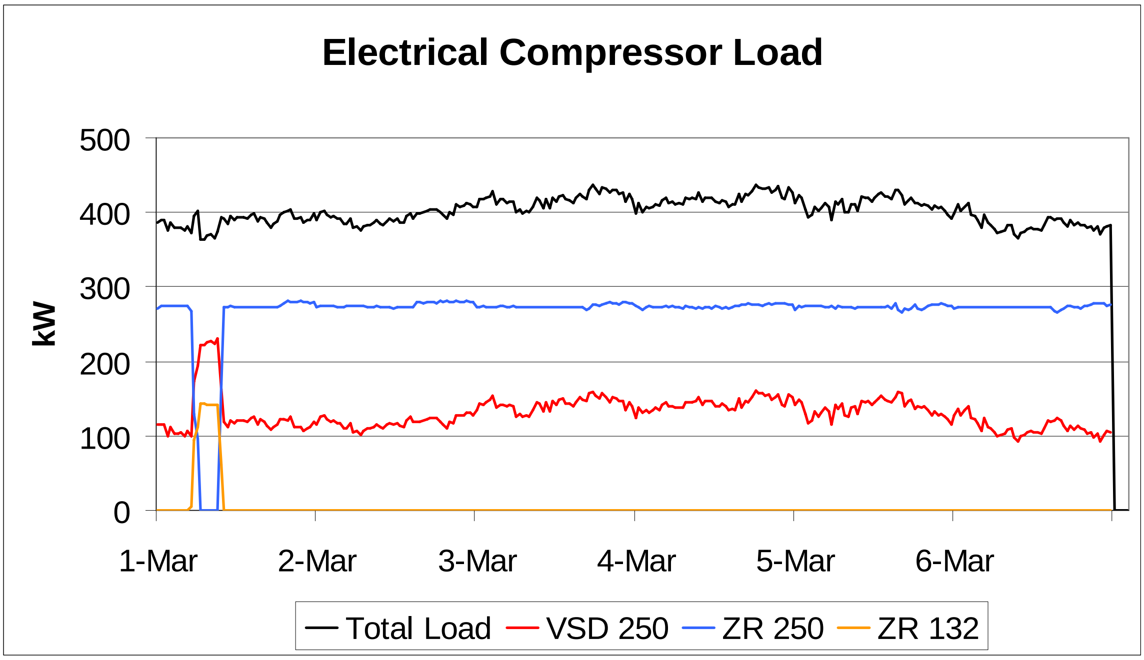
APPENDICES

Appendix A	**Te Rapa CAS - Specific power performance (2007)**
Appendix B	**Te Rapa CAS – System pressures (2007)**
Appendix C	**Te Rapa CAS – Electrical demand (2007)**
Appendix D	**Te Rapa CAS – Air flow rates (2007)**
Appendix E	**Monitoring and targeting a general description**
Appendix F	**CAS energy efficiency reporting at Te Rapa**
Appendix G	**International best practice programmes (Summary from the UK, USA, Germany and Australia)**
Appendix H	**Methods for increasing awareness of energy efficiency in CAS for the mass market**

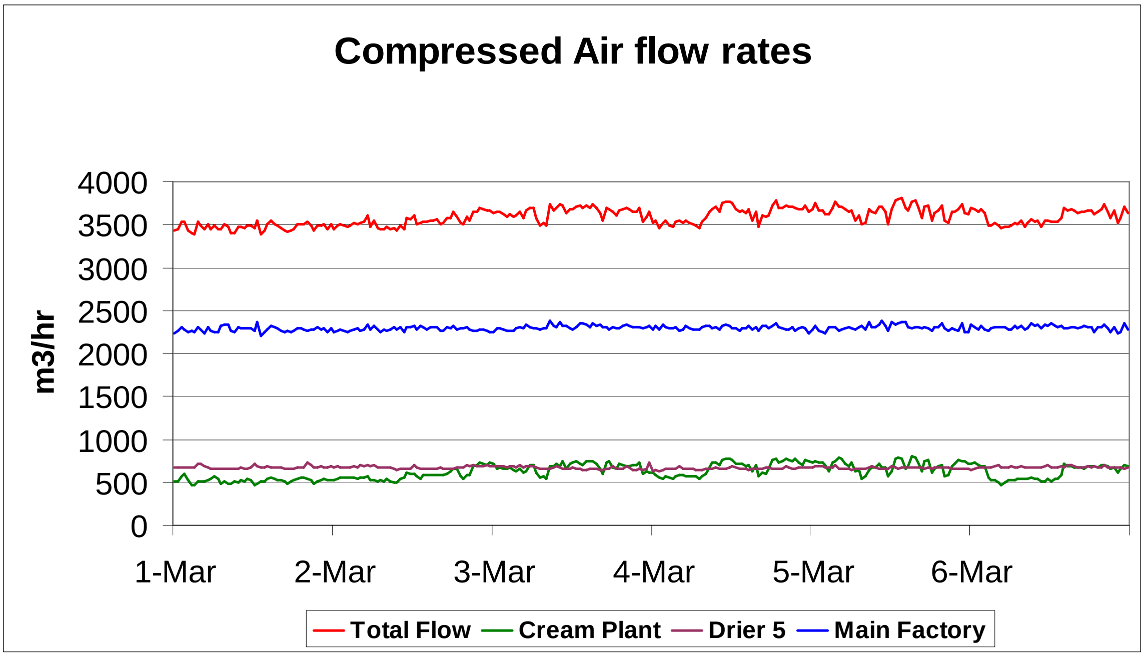
Appendix A Te Rapa CAS - Specific power performance (2007)



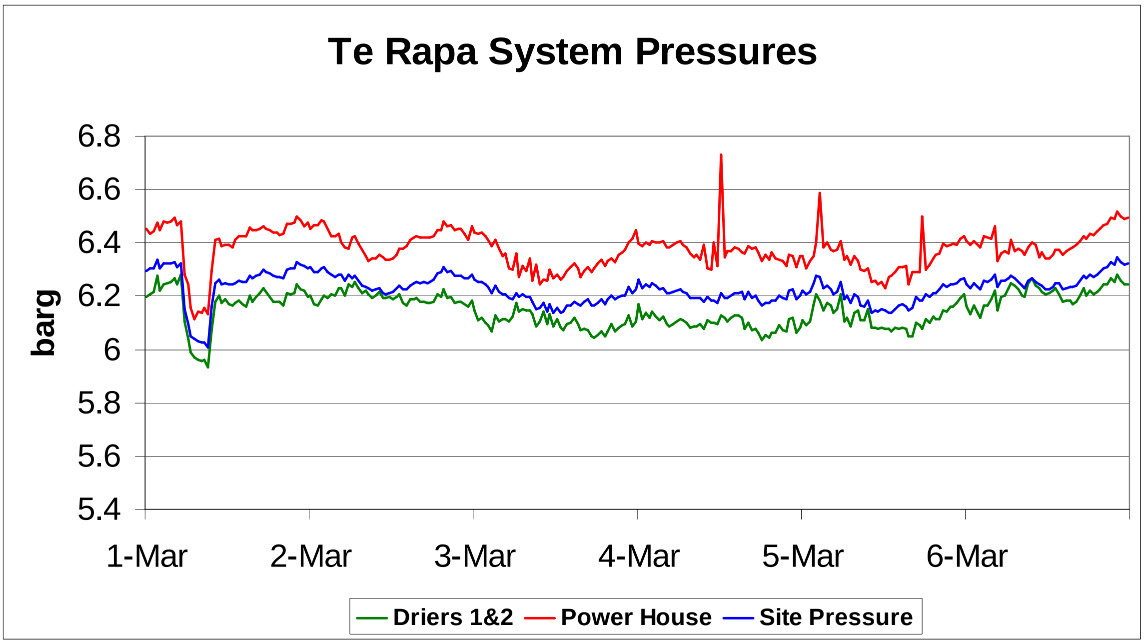
Appendix B Te Rapa CAS – Electrical demand (2007)



Appendix C Te Rapa CAS – Air flow rates (2007)



Appendix D Te Rapa CAS – System pressures (2007)



Appendix E Monitoring and targeting a general description

Introduction

Monitoring and Targeting (M&T) is an established technique to help reduce energy costs through improved energy efficiency and energy management control. Besides energy savings, Monitoring and Targeting as a technique can bring many other benefits such as: increased resource efficiency, better environmental performance, better production budgeting and will provide support to environmental management activities.

What is Monitoring and Targeting

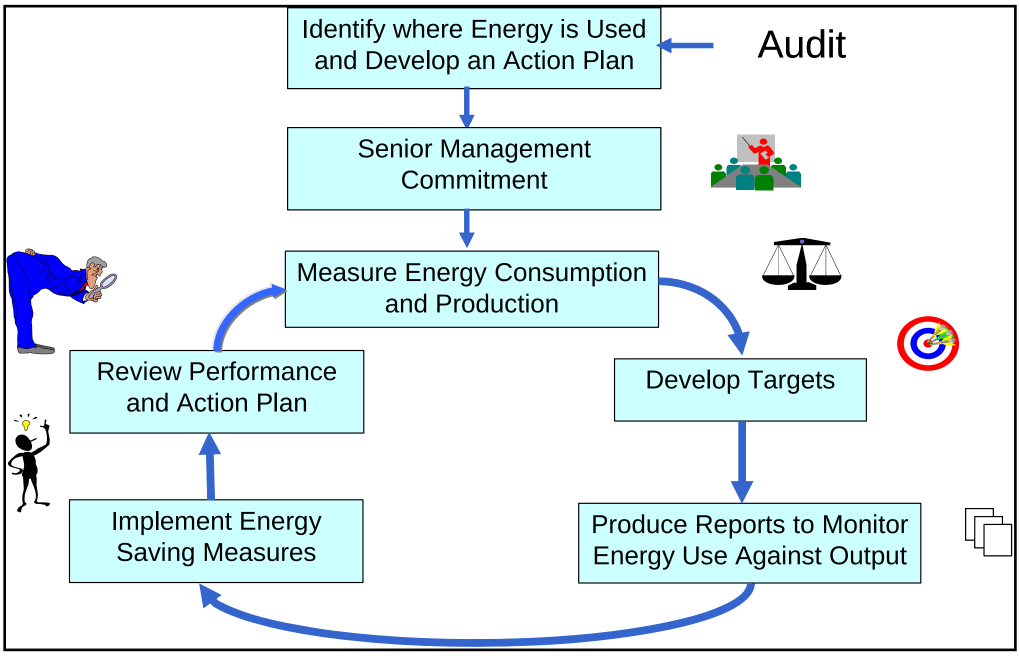
Monitoring and Targeting is the basis of any strategic approach to energy management. It requires a number of separate but co-ordinated activities to take place, following a clear process guided by the overall objectives.

Energy consumption information must be measured, interpreted and reported to measure and maintain performance, and to identify opportunities for improvement.

Accurate data must be collected at an appropriate time interval and stored. Historical consumption data must be analysed to develop targets, and new data compared to the targets to determine if consumption is better or worse compared to what was expected.

To make use of the results, performance must be publicised to all those in the organisation that have the authority to influence energy consumption. The report will also highlight the need for more detailed investigations, leading to process improvements.

This set of activities forms a cycle of action, measurement, analysis and reporting, as illustrated below:

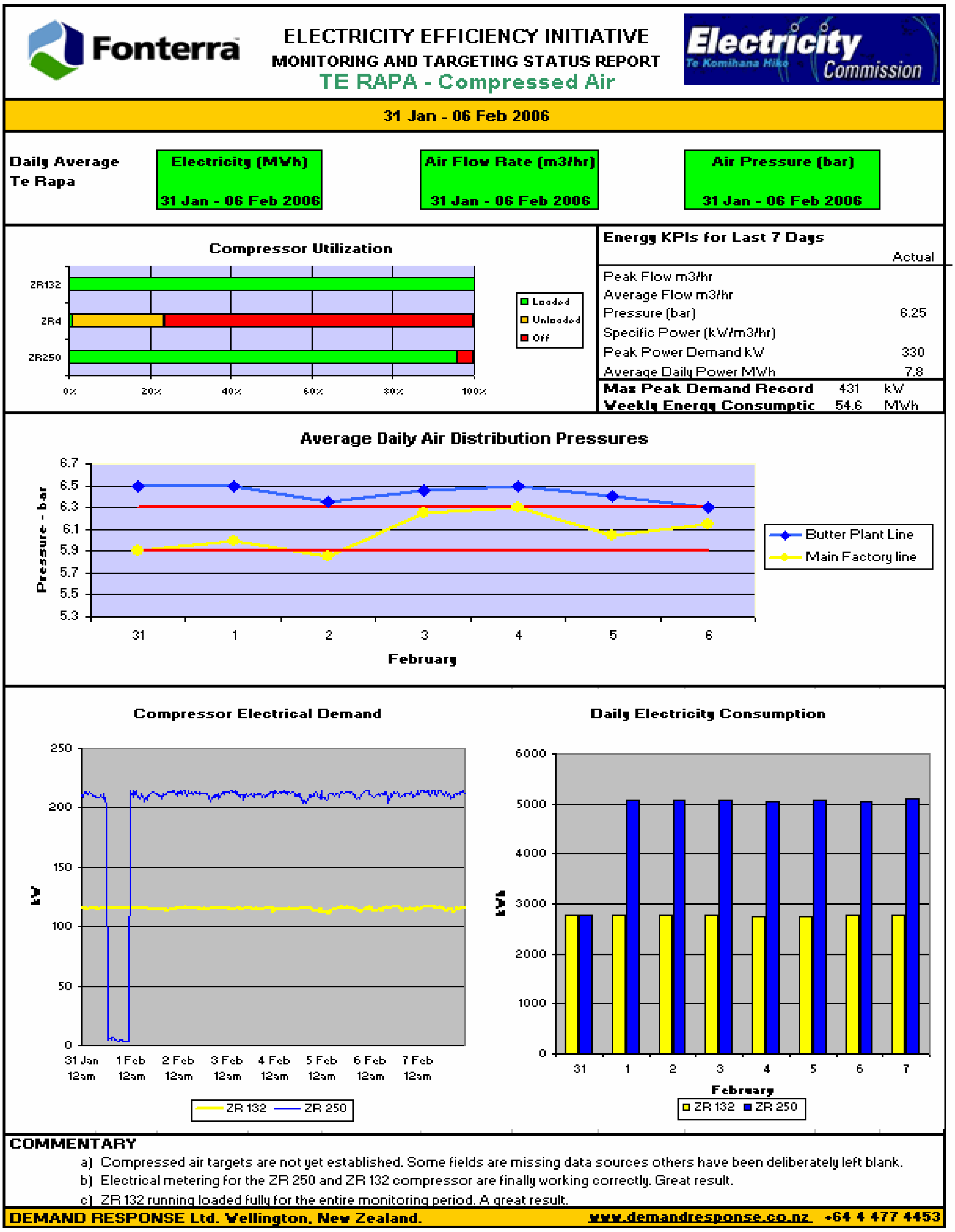


In summary, Monitoring and Targeting comprises:

1. The measurement of energy consumption and any underlying influencing factors;
2. The calculation of energy performance ratios;
3. The comparison of these ratios with expected values;
4. Communicating the results to the individuals or teams in the organisation who can respond;
5. The individuals or teams taking action to manage the energy performance.

Appendix F CAS energy efficiency reporting at Te Rapa

Version 1 report of CAS energy efficiency performance (31 Jan – 06 Feb 2006)



Fonterra

ELECTRICITY EFFICIENCY INITIATIVE
MONITORING AND TARGETING STATUS REPORT
TE RAPA - Compressed Air

Electricity Te Komihana Hiko Commission

31 Jan - 06 Feb 2006

Daily Average Te Rapa	Electricity (MWh)	Air Flow Rate (m3/hr)	Air Pressure (bar)
	31 Jan - 06 Feb 2006	31 Jan - 06 Feb 2006	31 Jan - 06 Feb 2006

Energy KPIs for Last 7 Days

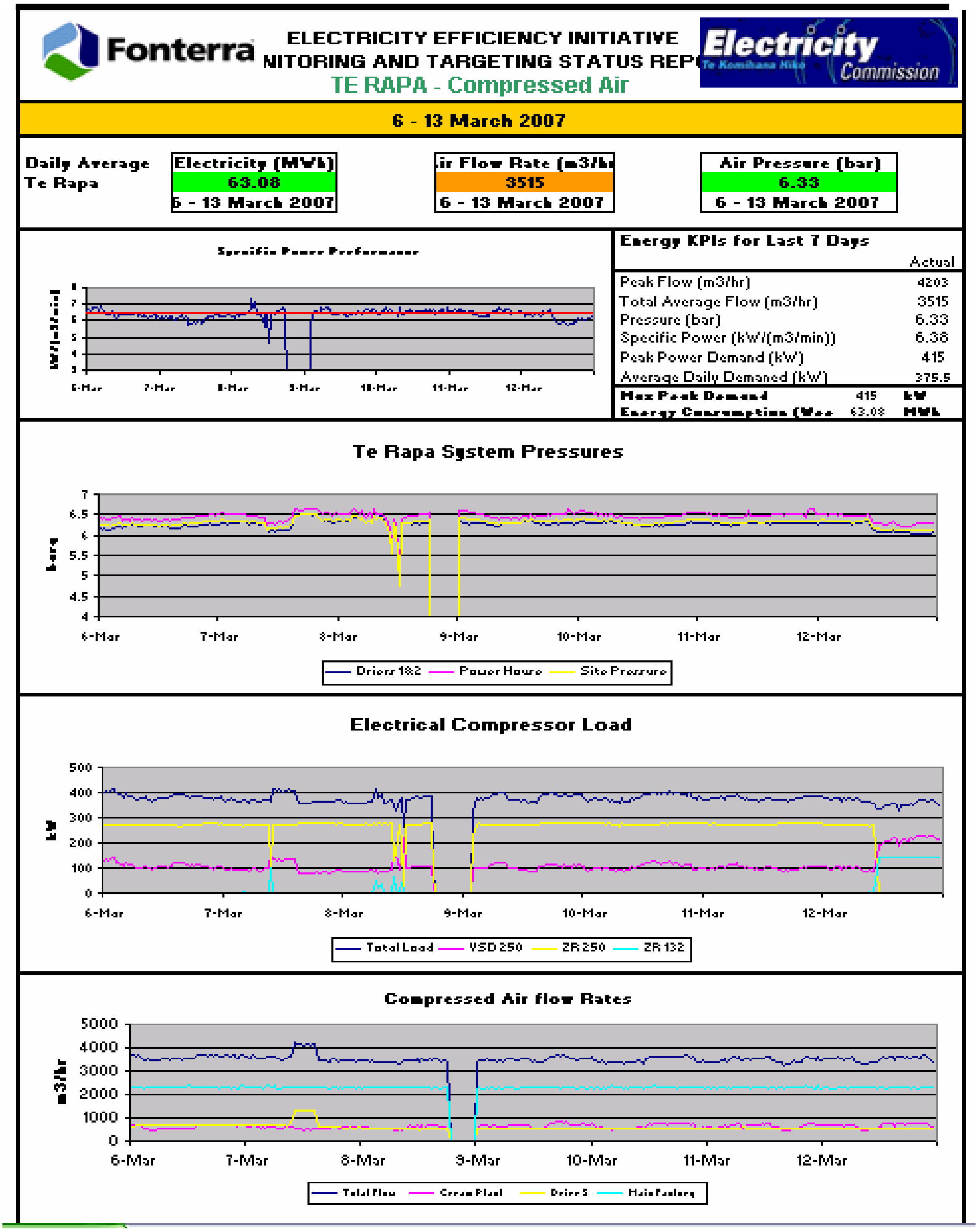
	Actual	
Peak Flow m3/hr		
Average Flow m3/hr		
Pressure (bar)	6.25	
Specific Power (kW/m3/hr)		
Peak Power Demand kW	330	
Average Daily Power MWh	7.8	
Max Peak Demand Record	431	kW
Weekly Energy Consumptic	54.6	MWh

COMMENTARY

a) Compressed air targets are not yet established. Some fields are missing data sources others have been deliberately left blank.
b) Electrical metering for the ZR 250 and ZR 132 compressor are finally working correctly. Great result.
c) ZR 132 running loaded fully for the entire monitoring period. A great result.

DEMAND RESPONSE Ltd. Wellington, New Zealand. **www.demandresponse.co.nz +64 4 477 4453**

Version 2 report of CAS energy efficiency performance (6-13 March 2007)



Fonterra

ELECTRICITY EFFICIENCY INITIATIVE
NITORING AND TARGETING STATUS REP

TE RAPA - Compressed Air

Electricity Commission Te Komihana Hiko

6 - 13 March 2007

Daily Average
Te Rapa

Electricity (MWh)	ir Flow Rate (m3/h	Air Pressure (bar)
63.08	3515	6.33
6 - 13 March 2007	6 - 13 March 2007	6 - 13 March 2007

Energy KPIs for Last 7 Days

	Actual
Peak Flow (m3/hr)	4203
Total Average Flow (m3/hr)	3515
Pressure (bar)	6.33
Specific Power (kW/(m3/min))	6.38
Peak Power Demand (kW)	415
Average Daily Demaned (kW)	375.5

Max Peak Demand	415	**kW**
Energy Consumption (Wee	63.08	**MWh**

Appendix G International best practice programmes (summary from the UK, USA, Germany and Australia)

This appendix intends to provide a synopsis of several best practice programmes for compressed air systems in operation around the world. Two extensively developed programmes are specifically detailed. The majority of the potential savings accrue from the improvement in the design operation and maintenance of the whole compressed air system and the associated down stream uses. The most significant barrier to improved efficiency appears to be the supply of information to the purchaser.

Compressed Air Challenge – USA

- Goals of the programme (10% energy savings, reduced operating costs, increased plant reliability).
- Programme participants are offered (a) facts sheets (b) resource texts (c) news letters (d) software packages (e) training seminars.
- Training courses are available and cover a wide range of material. Example subjects include: Taking measurements, developing a system profile, Air quality requirements, High pressure applications, High volume applications, CAS maintenance, viewing the system from the supply side, Understanding controls, Aligning supply with demand, Heat recovery, selling the project to management.
- A software package called AIR MASTER + is available. This interactive tool includes modelling and analysis applications. The package is down loadable from the internet and training is available.

Energy Efficiency best practice Programme – United Kingdom

- Technical guides are available online as a resource. The guides provide advice on things like calculating compressed air costs (generation, leakage, and treatment).
- Training courses are also offered to end users. Course content covers: CAS policy, maintenance, role of the work force to minimising waste, technical issues (energy efficient motors, VSDs).

Other best practice programmes have some notable features that are listed below:

- Customers can apply for financial incentives for technical research and plant equipment upgrades. Development of technology centres offering residential, commercial and industrial customers educational services and frameworks. Compressed Air Systems are displayed.
- Development of an A5 pocket book, with independent technical advice used by designers, constructors, installers and users.

The advantages and disadvantages of various best practice programme elements

1. **Technical guides and fact sheets.** Advantages: information can be quickly disseminated and users can select material specific to their requirements. Agreements could be reached with to share existing publications. A disadvantage is that it only provides generalised information and is the least engaging forms of communication.

2. **Comprehensive training manuals.** Advantage here is that they provide comprehensive information to be distributes broadly. Inclusion of relevant parties makes the manual useful to wide ranging parties and not just end users. Disadvantages are its generalised nature and passivity. Worksheets can be incorporated to record site specific information, this helps to stimulate engagement.

3. **Training courses.** Advantage. Feedback from the participants leads to sharing of experiences and the training provides empowerment. Disadvantages include cost and time constraints.

4. **Software and Web-based opportunities.** An Advantage is that sites can quickly tailor information to suit there needs. Down loadable software can reach a broad range for low cost. Disadvantage is the limitation in providing detailed customised advice. However, web tools rely on the user understanding and correctly collecting and interpreting information.

5. **On-site analysis and identification assistance.** The lead advantage is in providing better understanding, increases the success of continued action and engenders a spirit of support and participation. However, this element usually involved higher costs and resource commitments.

Several issues that were encountered during best practice programmes were identified as:

- Consulting engineers on fixed price contracts are only concerned with minimising initial capital costs.

- Simple housekeeping measures were often over looked (ventilation and reducing leaks).

- Measurement of compressed air systems is essential to the identification of poor performance.

Online resources

- Compressed Air Challenge www.compressedairchallenge.org

- Energy Efficiency best practice Programme www.thecarbontrust.co.uk/energy

Appendix H Methods for increasing awareness of energy efficiency in CAS for the mass market

The table below outlines the advantages and disadvantages of the various methods used to promote awareness of CAS energy efficiency.

Technical guides and fact sheets	
Advantages	**Disadvantages**
Information can be quickly disseminated and users can select material specific to their requirements. Agreements could be reached with to share existing publications.	It only provides generalised information and is the least engaging forms of communication.
Comprehensive training manuals	
Advantages	**Disadvantages**
They provide comprehensive information to be distributed broadly. Inclusion of relevant parties makes the manual useful to wide ranging parties and not just end users.	Its generalised nature and passivity. Worksheets can be incorporated to record site specific information, this helps to stimulate engagement.
Training courses	
Advantages	**Disadvantages**
Feedback from the participants leads to sharing of experiences and the training provides empowerment.	Cost and time constraints.
Software and web-bases opportunities	
Advantages	**Disadvantages**
Sites can quickly tailor information to suit their needs. Downloadable software can reach a broad range for low cost.	The limitation in providing detailed customised advice. However, web tools rely on the user understanding and correctly collecting and interpreting information.
Onsite analysis and identification assistance	
Advantages	**Disadvantages**
The lead advantage is in providing better understanding, increases the success of continued action and engenders a spirit of support and participation.	This element usually involved higher costs and resource commitments.