Compressed air systems:

Sealing up a productive manufacturing future for NSW

Executive summary

The modernisation and decarbonisation of Australia's manufacturing sector will require significant improvements in energy productivity – that is, gaining greater business value from energy used.

Often referred as the 'fourth utility' due to their essential contribution to manufacturing, compressed air systems (CAS) are estimated to account for around 16% of electricity use at typical manufacturing sites and 10% of total industrial electricity use (including large electricity intensive industries such as aluminium smelting). While easy to use, compressed air is also easy to lose. By not addressing the significant inefficiencies of compressed air systems, NSW businesses are wasting vast amounts of money, missing out on other potential business benefits beyond energy cost savings and will be unable to transition to Industry 4.0, the 21st century model for smart, decarbonised manufacturing.

This report has been funded by the NSW Department of Planning Industry and Environment (the Department) and details the results of the successful CAS pilot Offer delivered by the Department and the Australian Alliance for Energy Productivity (A2EP). The results highlight the enormous potential for NSW businesses – and industry as a whole – to improve energy productivity and competitiveness by addressing CAS waste.

The most notable barriers to understanding and addressing CAS waste in manufacturing businesses identified in this report include:

- insufficient remote monitoring of CAS performance to deliver understanding, control and business case data to responsible managers.
- the impact of split incentives across organisations creating a tragedy of the commons – benefits of acting are shared across business, not captured by those who incur the costs or do the work.
- industry incumbents not taking a total cost of ownership approach which would enable effective responses to CAS waste and the planning and implementation of alternatives.

Industry-wide CAS optimisation and transformation is an essential step for decarbonising industry and one that needs to start now due its complexity, its widespread use and the need to fit in with system/maintenance lifecycles. As well as detailing how businesses can address identified obstacles, this report also sets out recommended actions for businesses, industry associations, service providers and government.

80-90% of energy used by compressed air systems is wasted

Wastage usually due to:

- high rates of leakage
- maintenance of equipment
- very limited monitoring

10 main obstacles to CAS improvement have been identified

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5 recommended next steps for government and industry to address CAS wastage

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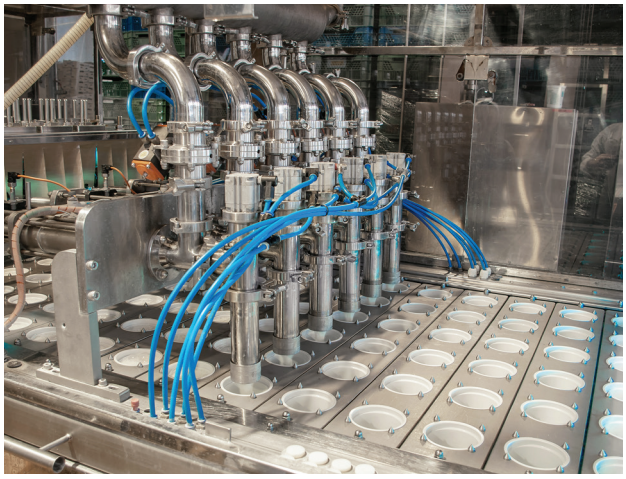
About the CAS Offer

CAS are widely used across industry for many different purposes, including conveying and sorting, powered tools, motors and pumps, provision of clean, dry heat, surface preparation, cooling, mixing, painting and vacuums. CAS are seen as essential, yet they are expensive to operate and maintain, inefficient (with 80 to 90% of the energy they consume wasted) and inflexible.



While the focus of many businesses with a CAS is maintenance, many don't realise that energy consumption actually comprises around 80% of overall CAS costs, ten times as much as maintenance[1]. The potential business value of productivity gains through optimisation and replacement of CAS is even greater, but rarely recognised.

The Department, in partnership with A2EP, developed and implemented an Offer designed to improve energy efficiency and cut carbon emissions from CAS.

As part of this Offer, A2EP delivered the following:

- Input to development of the Offer.
- Ongoing engagement with the Department project team to review progress and finetune implementation.
- Research and preparation of a paper on alternatives to CAS. This report broke new ground by documenting the variety of alternative technologies that could replace part or all of a CAS, offering electricity savings of up to 90% and a range of business productivity benefits beyond energy savings. These options also support implementation of Industry 4.0, a key means of enhancing business competitiveness and building a modern industrial model.
- Review of ten compressed air on-site assessments, with analysis provided to the Department.
- Planned, hosted and presented a workshop session on compressed air systems. This attracted 75 participants during the live online session and a further three views in the month following the event, and remains available online.

With Department staff, A2EP also conducted extended interviews with four industry consultants:

- Compressed Air Alliance
- Northmore Gordon
- Basil Greatrix
- ERM Power

These discussions flagged many issues that undermine optimal design, operation and maintenance of CAS across the manufacturing sector. They also highlighted limitations in the capabilities of CAS service providers and equipment suppliers, as discussed later in this report.

[1] Compressed Air Alliance 2020, *Compressed Air Workshop*. Australian Alliance for Energy Productivity. https://youtu.be/u4ES1IlDkHs

Offer outcomes

The Offer attracted around ten times as many applicants as expected. By the end of the initial phase of the Offer, the Department will have funded 130 on-site assessments of CAS at a diverse range of industrial sites.

Key features that underpinned the Offer's success included:

- **A simple application process** – consultants actively promoted the Offer to their existing clients and used it to attract new clients. In many cases, the consultant filled out application forms.
- **Sufficient funding** – the funding was sufficient to allow maintenance or other site-level staff to agree to participation without having to prepare a detailed business case or seek internal funding approval.
- **Clarity on compliance** - the requirements for compliance were reasonably clear and provided a financially viable offering for the service providers.

The quality of assessments varied. The best assessments:

- involved a leak survey,
- monitored compressor electricity use, air flow rates and pressures at key points in the CAS, and/or
- identified inappropriate or poor usage of compressed air and proposed more efficient alternatives.

Estimation of cost-effectiveness of measures typically focused on the value of energy saved and was usually presented using 'simple payback period' as a metric. Fixing leaks, rescheduling compressor operation, cleaning of filters and other adjustments were generally estimated to achieve payback periods of under a year, while delivering substantial energy savings. Replacement of CAS with alternatives had longer payback periods.

Offer findings at typical sites

Compressed air systems use accounted for 16% of site electricity use, translating to $90,000/year in energy costs

$50,000/year energy savings were identified with a simple payback period of six months

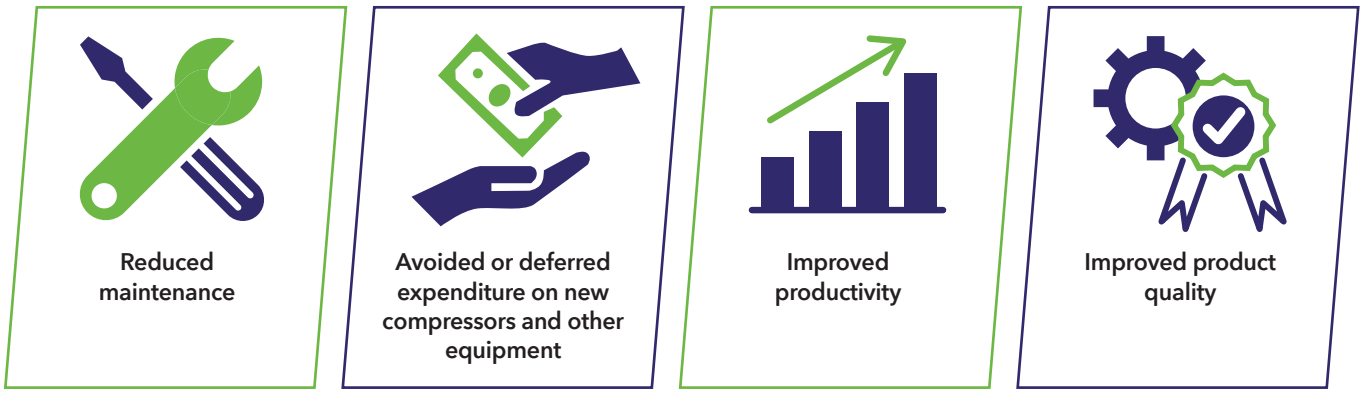
The assessments typically found high rates of air leakage, poor management of compressors and limited monitoring of performance. Based on a sample of 49 sites assessed, median CAS electricity consumption accounted for 16% of total site electricity use, costing around $90,000 for energy. Typical savings of $50,000 on annual energy costs were identified (of which air leaks comprised around $20,000), with typical simple payback periods of six months – often with rates of return on investment of well over 100% per annum. The table to the right summarises typical outcomes from the assessments.

In most cases, assessments identified additional savings and benefits, including reduced maintenance, avoided or deferred need to buy new compressors and other equipment, and process productivity benefits such as higher rates of production and improved product quality. These benefits were not included in the estimation of payback periods as their business value was not quantified in the assessments.

MEDIAN OUTCOME PER SITE	
Compressed air system sizes (kW)	125
Number of compressors	2
% of electricity use by CAS	16%
Electricity cost for CAS ($/year)	$89,500
System efficiency (kW/m³/min)	9.5
% air loss to leaks	27%
Cost of leaks ($/year)	$20,000
Total energy costs savings identified ($/year)	$50,067
Total energy cost savings	56%
Payback time for all measures (years)	0.5

Table 1: Median results from the study

Non-energy benefits identified:



Extrapolating the results from our sample of 49 sites to the whole NSW manufacturing sector, it seems that collectively CAS annual electricity consumption is the equivalent of more than 200,000 NSW homes at an annual cost of around $200 million. The potential energy cost savings across the state from addressing CAS inefficiencies would exceed $100 million annually, with all the costs of capturing these savings recovered within a year and a 100% per annum rate of return on investment! If the value of the non-energy benefits are factored in, the value of action to the state is even greater.

Reviews of assessment reports

A2EP reviewed ten CAS end-use reports to provide an independent perspective on their coverage and quality, and to identify common issues and lessons to assist with evaluation and future program development. The reports were selected by the Department to reflect a range of service providers and types of sites, they also highlighted the diverse range of services provided by CAS and the significant variation in the approaches used by service providers.

Relevant findings from these reviews included:

- Leakage levels were typically high, with the loss of 30 to 65% of compressed air produced.
- Few sites had monitoring beyond screens on compressors, which provided very limited data.
- Many compressors were old, oversized and/or suffered from issues such as clogged filters, undersized receivers, or overly hot environments, all of which adversely affect performance.
- Some assessments did not include detailed leak audits (this was a separately funded item).
- There was significant variation in approaches to monitoring. Most assessments only monitored compressor electricity use and relied on estimation of flow rates and pressure drops, as this level of monitoring was beyond the scope of the funding. This limited confidence in the validity of some recommendations.
- Due to the Offer timing, assessments were conducted in cool weather for sites which may have significant variations in production at various times of year, so recommendations regarding required CAS capacity may require further confirmation.
- Most sites used significant amounts of compressed air for activities that assessors deemed to be 'inappropriate' or 'poor' use of compressed air, based on the assessors' knowledge of alternative end-use technologies that they considered could perform the relevant tasks much more efficiently and/or effectively. Examples included using compressed air to blow dust off products, to cool equipment and to produce vacuums, all inefficient uses of CAS compared with other widely available options such as fans and electric motor-driven vacuum pumps.

Obstacles to improvements and savings

Despite a range of system fixes and alternatives being readily available, they are rarely implemented, so potential savings and other benefits are rarely enjoyed. The Offer provided insights on the obstacles, the understanding of which is essential to overcoming them.

Lack of data on CAS performance and costs – when there is monitoring, it is rarely effectively utilised

Finance managers often don't recognise the importance and potential returns of monitoring and reporting. Existing monitoring systems are often not effectively utilised due to not being user-friendly, a lack of staff training and/or the valuable information not being delivered in a timely manner.

Capital expenditure decisions are made infrequently and usually in crisis mode, focusing on individual elements which have failed and are impacting production.

These circumstances limit the scope to consider combinations of changes that could optimise costs and capture maximum benefit. For example, repair of leaks and replacement of some end-use equipment with efficient alternatives could lead to selection of a smaller replacement compressor.

Regular leak audits and system optimisation are the exception, not standard practice

In most cases, leak audits only take place when there is a crisis in the system and efforts are reactive rather than focussed on the overall system and long-term performance and optimisation.

Little in-house CAS expertise and a lack of industry expertise in CAS efficiency and optimisation

Several service providers mentioned that due to a lack of in-house CAS expertise compressor manufacturers were often relied on for maintenance and advice, but their priorities did not necessarily match those of the client or consider optimisation of overall system efficiency. In some cases, adjustments made by compressor suppliers increased energy use. The lack of expertise in CAS efficiency is notable.

Low awareness of non-energy benefits from CAS optimisation or alternatives

Most service providers delivering CAS services considered only energy cost savings in their financial analyses. Some mentioned potential additional benefits in broad terms. This meant that the multiple benefits beyond energy savings were not quantified or effectively emphasised, even though studies[2,3] show that these can be of far greater value to a business.

[2] International Energy Agency, 2014, *Capturing the Multiple Benefits of Energy Efficiency*, Paris.
[3] International Energy Agency, 2018, *Energy Efficiency 2018*, Paris.

Organisational obstacles

During the Offer, a number of obstacles specifically related to organisation issues, processes and decision criteria were found to undermine adoption of improvements. These included:

- **Very high rates of return on investment were expected from CAS projects** – often under a one to two-year payback period due to factors such as the time and effort required to gain capex approval from finance or management. A useful question to ask of a senior manager is 'which would be easier in your business, getting capex approval for a new air compressor based on concern that the existing one may fail or be too small, or an increase in operating budget for the maintenance group to progressively install monitoring systems to support preventive maintenance and ongoing leak repairs so the existing compressor remains adequate?'

- **Site staff typically need to gain management approval** if an assessment or action involves significant capex or cost, typically for costs more than about $5000. This may include preparing a business case, trying to explain to non-technical decision-makers why this is significant to the business, etc. This not only requires key skills and data that often does not exist, but also creates a 'hassle factor' for staff with heavy workloads that may undermine motivation for action.

- **Replacing 'payback period' with 'return on investment'.** While common in business, use of 'payback period' as a decision criterion is widely recognised as a 'pessimistic' indicator. It implies that the investor is 'financially behind' until the payback period is passed. In reality the investment may offer a high annual rate of return on investment and high net present value. It may also increase business asset value by a factor several times its cost, as asset value is commonly linked to net annual profit, which is increased by savings on CAS operation and capital. A useful calculator for cost-effectiveness of a measure can be found at Energy Economics (energytools.com) it presents results in terms of payback period, internal rate of return (or return on investment) and net present value.

- **Split incentives leading to 'tragedy of the commons'** - a situation where one cost centre incurs costs, spends time and takes responsibility, while the resulting benefits are reflected in savings or other benefits to other cost centres and staff. Imperfect internal accounting systems and lack of understanding of the roles of others are key causes, especially in relation to activities that cross traditional organisational boundaries.

- **Perceived risk of change** is a common problem at individual, manager and organisational levels. CAS reliability underpins production and business revenue so there is often reluctance to make changes that do not offer obvious and rapid returns: 'if it ain't broken don't touch it'. A lack of familiarity with alternatives, lack of access to a trusted supply chain or expert advice, or inadequate evaluation of benefits may amplify perceived risk. Attempts to extend the life of 'sunk capital' instead of incurring costs associated with profitable upgrade or replacement investments are common. This can undermine cost-effective investment in monitoring, design and equipment.

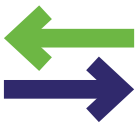
Addressing CAS inefficiencies

There are four key areas for ensuring CAS good practice and efficiency:

Organisational context
Key roles across an organisation must deliver information, appropriate funding and resourcing, streamlined decision-making and incentives.

Effective system assessment
An essential first step and basis for a longer term CAS strategy, costs of asssessments and actions will typically be recovered in months.

Ongoing good practice for management and optimisation
Processes, staff training and smart monitoring to enable performance monitoring, awareness of and action on faults.



Consideration/transition to CAS alternatives
Overall CAS management should include considering alternatives that offer efficiency and broader business benefits.

Organisational context for CAS optimisation

The organisational structure must deliver:

- **Information** – so that performance can be benchmarked, problems can be identified (preferably before they impact on production), maintenance can be scheduled, and the effectiveness of repairs or changes tracked.
- **Appropriate funding and resourcing** – for maintenance, operation, capital investment, monitoring, training and a 'watching brief' to track potentially useful technology and service changes. Funding should be based on net overall business benefit over time, not just capital costs. 'Split incentives', where one does the work and another gains the benefit, between cost centres and functional groups must be avoided.
- **Streamlined decision-making** – to minimise cultural, institutional, financial management and resource barriers to optimum action.
- **Incentives** – so that each decision-maker sees benefit, not risk or blame.
- **'Futureproofing'** – to factor in capacity to adjust to future potential changes in level of production, product characteristics and process technology developments, as well as external factors such as climate policy and strategy and workplace health and safety to support long-term business success.

The best first step? A good CAS assessment

Based on the experience gained through the Offer, an effective CAS assessment is considered an essential first step. Typically, costs of assessment and actions with high rates of return will be recovered in under a year. It will also provide a basis for a long-term CAS strategy.

Key features of an effective assessment include:

1. Selecting an **experienced compressed air specialist** with a track record of delivered savings, and ensure they agree to implement the actions listed here. The specialist should also be briefed on the business' product/service, targets and future strategies so these can be taken into account in determining recommendations.

2. **Real-time measurement** of CAS electricity use, air flow rates and pressures at key points around the system for at least a week of representative activity. CAS electricity use during this period should be compared with likely process requirements across the seasons and under varying weather conditions. For example, production may vary in different seasons, and CAS performance varies with air temperature and humidity, so it is important to check that the operating conditions of the CAS are representative of those at other times, or to adjust analysis and recommendations so that actions based on the week-long assessment period will be valid at all times.

3. A **thorough leak survey** using an ultrasonic sensing device. All leaks identified should be tagged and photographed. The replacement parts and actions required to address each leak should be documented in sufficient detail for in-house staff to be able to procure the components and make the repairs. Where in-house capacity is limited, this information will allow the business to seek competitive quotes.

4. A **site inspection** to identify issues such as unnecessarily warm inlet air to compressors, clogged filters, damaged equipment, etc. A high-level drawing of the CAS layout and end uses on a site plan should be prepared and appropriately labelled. The functional end uses of major items of equipment (e.g., drying, cooling, vacuum, fitting caps, screw-fixing, etc.) should be noted. This information will underpin ongoing maintenance and evaluation of options that could replace some or all CAS use (as discussed later in the section 'Smarter alternatives to improve overall productivity')

5. **Analysis of the monitored data** should include checking the scheduling and operation of compressors and comparison against appropriate benchmarks such as operating pressures.

6. **Graphs of CAS electricity consumption versus production** and/or major process inputs should be prepared, so that 'energy overheads' and marginal energy use per unit of production can be explored and used for benchmarking and preventive maintenance.

7. **A report and presentations tailored to relevant staff for review**, including the maintenance and technical manager, and the energy procurement and finance managers. There should be a process to gain clear agreement regarding implementation of measures that meet organisational criteria. Consideration should also be given to establishing ongoing CAS management procedures, accountabilities and strategy as part of the firm's ongoing environmental, energy or overall management system.

Implementing a CAS management system for good practice

A CAS management system which is integrated with business strategies needs to be established to ensure ongoing good CAS practice. It will require allocation of funds and resources, staff training and should include the following:

Real-time monitoring and feedback on electricity use by CAS, air flow rates, pressures are essential. These can then be benchmarked against system performance after an audit and report real-time indicators such as CAS electricity per unit of production (and/or key process inputs).

Effective remote real-time monitoring can flag emerging problems early or in between leak audits, so timely action can be planned and implemented.

Simple processes for funding of CAS monitoring, data analytics and maintenance should be established and prioritised to defer, reduce or avoid CAS capital expenditure.

A review of CAS should be included when any major process change or plant investment is being considered to identify the possible reduction, removal and/or replacement with more productive alternatives.

Transitioning beyond compressed air

A CAS delivers energy in the form of compressed air that can drive actuators, move items, dry components and perform many other tasks. The wide range of tasks it can power, the relatively low cost and light weight of end-use equipment have traditionally compensated for its limitations. A lack of obvious alternatives has only reinforced its use, often for tasks unsuited to compressed air.

However, emerging 21st century alternatives can not only achieve the same tasks faster and more precisely, but they can also collect data, exchange information and intelligently manage quality control. These alternatives can transform a business model and integrate a process into a more sophisticated and productive business system delivering broad benefits beyond just energy and cost savings.

Transition can occur in stages

To begin to capture the many benefits of alternatives to CAS need not involve radical change. Contrary to common assumptions, this transformation can occur in stages – it's not an all-or-nothing, risky revolution which will massively interrupt production. A staged approach allows staff to familiarise themselves with new systems, trials of new product/service providers, staff training, phased development of data and communication systems, etc. Transition can be staged in several ways, for example:

- **Installing sensors and monitoring systems** that can be connected to existing on-site data systems and/or beyond the site via secure gateways to make use of data from other sources and share data. Providing the right data at the right time, in the right form to the right person or equipment can transform business productivity.
- **Selected compressed air powered actuators or other items of equipment can be progressively replaced by alternatives.** This approach allows a gradual transition. Criteria for seeking alternatives could include need for replacement of existing equipment, selection of 'non-critical' equipment for a trial, opportunity to remove a bottleneck or speed up part of a process, perceived value in accessing data at a particular part of the plant, etc.
- **Part of a CAS may be replaced based on a variety of criteria.** For example, equipment that runs outside the times when the main CAS operates, part of the process that is suited to an alternative technology, equipment that is located a long way from the main CAS, equipment that operates at a different pressure from the rest of the plant, etc

Smarter alternatives to improve overall productivity

Figure 1 compares traditional CAS use in a production process with a scenario using alternatives, illustrating how these alternatives can add a new dimension to business productivity, particularly with the real-time information flows they enable. The information that can be collected from multiple sources or provided to relevant partners on-site, across business boundaries, and other sources such as weather, traffic conditions and statistics, can be used to enhance business productivity in many ways.

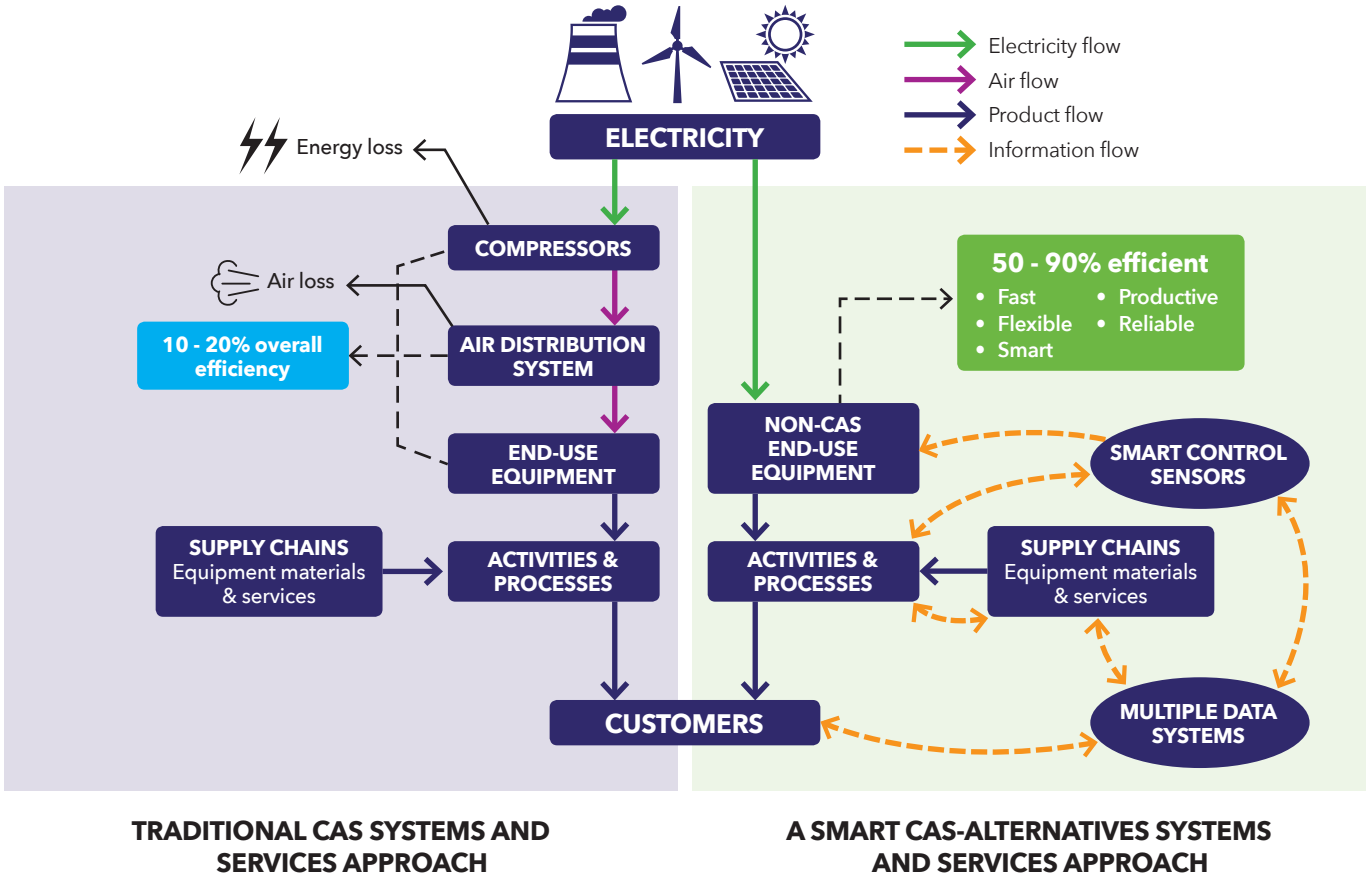


Figure 1. Alternatives to CAS support increased business productivity

Alternatives to CAS are discussed in the following section. The A2EP report on compressed air alternatives for the Department (August 2020) provides much more information about alternatives to compressed air, and links to suppliers and sources of additional information. It also provides examples of practical applications at sites.

Capturing business benefits through innovation

Application of a 'systems and services' approach before selection of equipment can open up new business models and opportunities for cooperation. This involves asking what fundamental services are actually required, and what systems (technical, skills, organisational models, supply chains, distribution to customers, etc.) might best deliver those services. For example, saving money by outsourcing some process or fabrication, redesigning a product or packaging, using different materials to remove the need for processes or reducing the weight of materials to open up new options for materials management.

Next steps – future directions for CAS

The Department's Offer has certainly confirmed not just the high energy and air wastage from CAS use in NSW industry, but also an appetite in industry to address the waste and uncover potential cost savings and other benefits. It has also framed the business benefits of smart, flexible, connected technologies. However, we can see that further work is needed to help businesses overcome the obstacles to implementing improvements, and to create the tools and programs for take-up across a range of industries.

The following suggestions respond to the issues and barriers observed by A2EP during involvement in the Offer. There is potential for industry associations, service providers, financiers, businesses and/or government agencies to address these issues in a variety of ways. Many are potentially relevant to other manufacturing activities and program areas.

Follow up participants in the Offer

The Department's CAS Offer provided financial support for manufacturers to access leak surveys and end-use reviews. It did not directly support implementation of resulting recommendations. However, the guidelines for service providers were intended to encourage participating businesses to take action by highlighting benefits (particularly value of energy savings), providing practical information such as documentation of leaks and specific actions, and building relationships with service providers.

Future follow-up with the businesses in the Offer is important to understand which businesses have acted on the advice provided, how they acted, what lessons have been learned and why other businesses haven't acted. This offers potential to document and promote successes and ways of overcoming barriers, and to learn from experience.

Examples of potential actions linked to follow-up could include case studies, presentations in conferences and workshops, integration into training programs, continuous professional development (CPD) credits and certification, development and roll-out of financial products, and individual business-level strategies.

Build awareness of multiple benefits of action beyond reduction of energy costs

Management attention is more likely to be gained if changes can offer broader business benefits such as increased rates of production, reduced reject rates and waste, enhanced consistency and quality, improved allocation of staff resources and/or improved WH&S. This is a broad challenge across most energy productivity/efficiency fields.

Experience from the Offer that supports a case for further action to build awareness of the broader benefits focussing on CAS includes:

- The Offer has already built up data, service provider competence and relationships, and an initial business case for action at many sites.
- Typically, CAS is extremely inefficient (80-95% energy waste) and plays a core role in maintaining production – it should be given priority attention within well-run manufacturing businesses.
- Emerging smart connected alternatives can partially or completely replace CAS while introducing modern business productivity practices such as Industry 4.0.

- Quality of CAS assessments was variable. The quality of CAS services and auditing could be improved, for example through working with industry associations to develop training and certification systems, 'best practice' guidelines for assessments and CAS management, and transition to options beyond CAS.

This awareness challenge is exacerbated by hurdles demanding extremely high rates of return on CAS investment and organisational issues also discussed in this section of the report.

Accelerate adoption of comprehensive remote real-time monitoring and data analytics

The Offer showed that CAS at many sites has little or no monitoring or benchmarking of performance. Where it does exist, it usually does not monitor all key variables or produce useful and timely indicators for operators or management, and it is rarely utilised. Key factors underpinning this problem are the up-front costs of monitoring equipment, and the lack of recognition of its value by both decision-makers, such as finance and management teams and production staff. This is often reinforced by unfortunate experience of limited outcomes often gained from previous investments in traditional sub-metering and monitoring technologies and services.

The transformational benefits of best practice monitoring and analytics are just one aspect of those delivered by a broader 'Industry 4.0' approach. Options to accelerate monitoring and data analytics include:

- **'Monitoring as a service'**, financed by service providers or third parties such as partners of the Clean Energy Finance Corporation (CEFC).
- **Low interest, long term or 'soft' loans** repayable from savings or other financing models such as energy performance contracts and government incentive or grant schemes.
- **Education of finance staff** regarding the multiple benefits of having 'the right information at the right time and place, in the right, actionable form'. Finance staff should be encouraged to reflect on how important good quality data are for their work and consider why this should not be equally important for others working within their company.
- **Demonstration projects** that document the benefits and illustrate effective techniques.
- **Guidelines for best practice monitoring/data analytics/benchmarking indicators/feedback** to operators and decision-makers, including tracking of CAS electricity use, compressed air flows and pressures and indicators such as electricity and compressed air consumption per unit of real time production.
- **Highlighting the business value that can be gained by connected data solutions** reporting key process indicators and business diagnostic indicators using multiple data streams from across the business and value chain, and from external sources such as weather data, energy prices, variations in product and input prices, etc.

Accelerate shift of part or whole manufacturing sites away from CAS use

There are potentially enormous productivity and other benefits from a shift from traditional manufacturing technologies to a range of smart, flexible, connected, often modular and electric options. These can transform manufacturing business models and productivity. This potential is described in the A2EP report and guide to energy productivity and Industry 4.0 in manufacturing. The 'alternatives' report for this project and the presentation at the CAS workshop by Alan Pears, Senior Industry Fellow at RMIT and author of this report, focus on the CAS aspects.

Experience from the Offer showed that CAS were being used for many 'inappropriate' or 'poorly suited' tasks where other existing solutions could deliver services more efficiently, effectively and economically. Beyond these existing options, there was little awareness of, or interest in, applying emerging advanced options. In the context of the urgent need to innovate and improve productivity, this is an issue of concern, where inaction will increasingly undermine competitiveness of Australian manufacturing.

The impression gained during research was that the supply chains delivering advanced alternatives to CAS in Australia are fragmented and immature compared with advanced economies such as Germany. Where they exist, they have found it difficult to break into existing supply chains and build partnerships with incumbent service providers.

This difficulty in competing with incumbent equipment and maintenance providers has been an issue for competent CAS improvement service providers, too. Limited in-house expertise, resources and strategic focus has meant that many sites rely heavily on suppliers of compressors or other existing equipment for advice and services. This can lead to sub-optimal outcomes due to knowledge limitations and differing priorities.

The transformation of CAS is a subset of the transformation of manufacturing that is emerging and urgently needed. In principle, there are several potential pathways:

- CAS could be used as an example of how transition to Industry 4.0 could be pursued in Australian industry.
- Providers of Industry 4.0 solutions could be encouraged to emphasise CAS alternatives in their range of offerings.
- CAS transition demonstration and pilot projects could be developed, funded and promoted through agencies using models based on those used by the Australian Renewable Energy Agency (ARENA) and the CEFC, progressive industry organisations, product and service providers, or government initiatives.
- Training and education organisations could be encouraged to upskill people from across trades and professions in CAS alternatives. Vacation students, student projects and traineeships could play useful roles in transformation.
- Model specifications/recommendations for new systems and an advisory service to help businesses to identify and source appropriate equipment and expertise
- Incentives could be offered to designers and hosts of greenfield sites incorporating alternatives to CAS.

Develop and implement strategies that target internal organisational obstacles

During the Offer, a number of internal organisational issues, processes and decision criteria were found to undermine adoption of improvements. These organisational imperfections and distortions have significant adverse impacts for innovation and competitiveness more broadly.

Options for action to address these issues include:

- **Training programs** developed with professional organisations of financial and technical staff with CPD credits or other certification that is recognised by employers. Engagement processes could include concise guides for leaders in the different parts of the business who need to work together to deliver collective benefits.
- Cross-organisation strategy development **workshops to build relationships and transfer skills**.
- Work with CEFC and fiduciary regulators to **educate financial staff** on energy and climate-related investment and risk.
- **Government agencies could develop requirements** for access to government schemes include specifications/ recommendations for best practice CAS audits, new systems and services, and buyer alliances to help businesses to identify and source appropriate equipment and service providers.
- Skill up industry associations, manufacturing businesses and service providers to encourage **development of supply chains that overcome barriers** such as fragmentation and potential conflicts of interest between supplier and customer.
- **Emphasise energy market opportunities** (such as demand response) and climate response benefits (such as pressure from customers).
- **Use students for 'watching brief' and 'fresh eyes'** to track innovation, evaluate effectiveness of organisational systems, etc.
- **Develop and promote industry capacity to deliver interim measures** to provide cover during crises so production can continue, and appropriate consideration be given to alternatives.
- Encourage **documentation of impacts of crises to build a business case** for future digitalisation and analytics so that, among other benefits, problems can be detected and addressed before they impact on production. The documentation of impacts can also support the creation and maintenance of contingency strategies.

Compressed air improvements: ROI vs difficulty

Both return on investment (ROI) and difficulty of implementation can be major barriers to action - and they are not necessarily related: a high ROI measure can be easy or difficult to implement. An understanding of these factors can assist a manager to develop a practical strategy to capture maximum benefit while using resources effectively. For example, a focus on fixing the 'easy to fix' leaks provides an opportunity to develop staff skills, learn to judge how much time may be needed, develop relationships with supply chains and build capability and confdence to address the last few 'difficult' leaks, which still offer a high rate of return.

This situation is illustrated in Figure 2 which shows the ROI and 'degree of difficulty of implementation'. The illustration provides indicative insights into a range of options and their relative return on investment and implementation difficulty. Note that ROI reflects the annual return on investment, usually expressed as a percentage return. This can be compared with the interest rate paid on borrowings, or the after-tax return on money invested in a bank. At present, interest on both invested funds and borrowings are at record lows, so business investments in CAS improvements can be much more attractive.

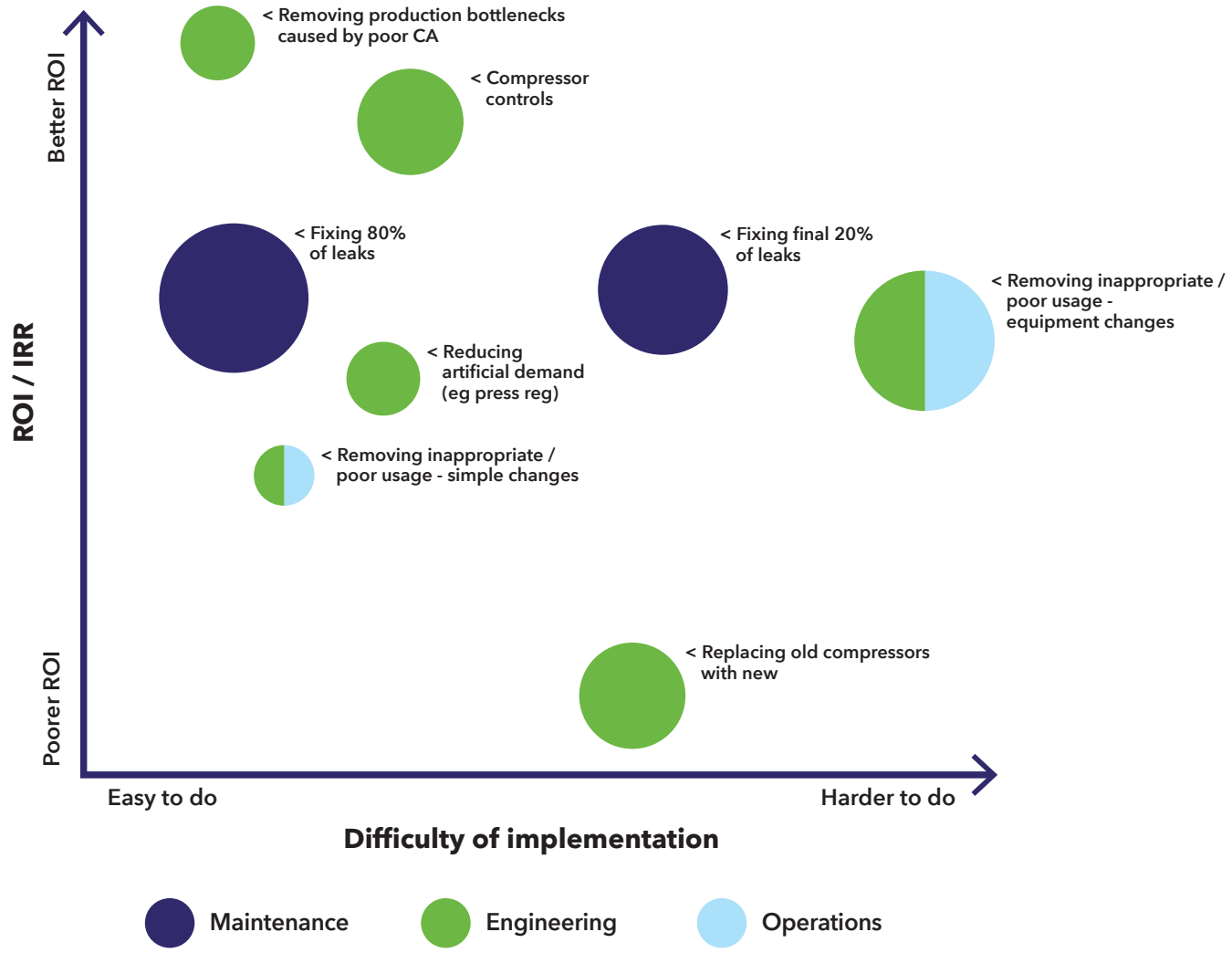


Figure 2: ROI versus degree of difficulty implementing CAS improvements.

As mentioned previously, various system improvements and efficiency fixes exist which can typically offer sites annual savings of $50,000 with a payback period of around six months. In the air use reviews from the Offer, recommended actions offered ROIs of 15 to 200% per annum based on energy cost savings alone, while potentially delivering other business benefits and improved asset value as well.

A new compressor scores fairly well on implementation difficulty, but poorly on rate of ROI compared with a range of alternative strategies. It does not improve reliability and performance of the rest of the CAS, nor does it underpin plant modernisation that could improve process productivity. However, the illustration also shows that a more productive business strategy for CAS is more complicated. It will require planning and management, allocation of staff resources, and possibly engagement with different contractors. But it's worth it.

A range of simple, cost-effective options are outlined in the Department's Compressed Air Guide (2017). A number of these actions are presented in Figure 2 above to show return on investment versus difficulty of implementation. Presenting them as investments that will deliver ongoing returns across the business will aid in making a business case and securing the funding needed to make major comprehensive improvements or implement alternatives.

Strategic decision-making on CAS – tricks and traps

- It's common for many sites with a CAS to think of replacing an old or undersized compressor with a nice, shiny new one: it will probably be a bit more efficient than the old one, and it should be more reliable. This is a once-off decision that offers a tangible and easily implemented solution that may even be offered by the existing compressor supplier who already has a maintenance contract. But is it a better investment than other options? Is the existing compressor in fact 'undersized' because there are many air leaks, clogged filters, undersized air receivers or wasteful applications of compressed air?
- Would other investments, possibly combined with changes to work practices, offer a better outcome? For example, improved monitoring and control can support preventive maintenance to improve overall system reliability, not just compressor performance. Informed replacement of end-use equipment (that use compressed air inefficiently) with modern alternatives can offer a much better investment return.
- And don't just cherry-pick the 'easy' measures. The 'difficult' measures can make implementation of 'easy' measures more effective, for example, most leaks must be fixed before the full benefits of increased CAS output and lower running costs will be captured. Fixing a few leaks increases system pressure and increases the leakage from the remaining leaks.

  The 'difficult' measures can also provide broader business benefits: replacing CAS equipment with fast, flexible, smart, adaptable and connected equipment can speed up production lines and reduce reject rates, bringing benefits far beyond the value of the energy being saved.

Conclusion

Many valuable insights have been gained from design and implementation of the Department's CAS Offer to NSW business. More than 130 businesses have been provided with information to support action to capture substantial cost savings and business benefits in their operations where existing practices typically far from optimal.

Extrapolation of the Offer results suggest that NSW industry is spending around $200 million on energy for compressed air, with 80 to 95% of that energy wasted. The potential for annual energy cost savings of over $100 million seems to exist. Productivity benefits could multiply these savings.

Emerging smart, flexible, connected electric alternatives could replace much existing CAS use, providing energy savings of 50 to 90% and substantial business productivity benefits resulting from provision of timely information to optimise operations, increased process speed and precision, and enhanced interaction with supply chains and customers.

Engagement with service providers and users during implementation of the Offer, as well as research and analysis, has identified numerous options for future action. CAS users, service providers, industry associations, educators and governments could deliver transformative business outcomes that would enhance competitiveness and be an essential step in decarbonising the economy and driving the adoption of 21st century business practices, such as Industry 4.0.

AUTHORSHIP OF THIS REPORT

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ABOUT A2EP

A2EP is an independent, not-for-profit coalition of business, government and research leaders helping Australian businesses pursue a cleaner and more successful future by producing more with less energy.

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