Report

Interventions Analysis: Compressed Air and Electric Motors

Prepared for

Electricity Commission

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Executive Summary

This report considers the case for intervention by the Electricity Commission to promote better electricity efficiency in the area of compressed air systems and electric motors. It draws in part on earlier work completed for the Commission. That work comprised separate technical investigations into the efficiency and conservation potential of motors and compressed air. The close relationship between these uses has also been recognised: compressed air systems (CAS) are frequently powered by electric motors.

We estimate the value of electricity saved through efficiency measures at 7.5c per kWh in the short run. Over the longer term, the cumulative effect of these and other demand side measures will yield some additional savings in transmission and distribution network investment. The lumpy nature of those investments, combined with uncertainty over the location and peak-load impacts of demand side efficiencies, make estimates of long run savings very complex. We have not been able to resolve them in this project, relying instead on the proxy measure provided by the price to end-users of transmission and distribution services.

The existence of a market failure is a pre-requisite to industrial interventions that use public funds. We evaluate the problems that are said to give rise to demand side efficiency potential, to determine whether they are actually market failures. That analysis concludes that the low priority firms attach to energy efficiency initiatives is not necessarily a market failure; rather it may be a reflection of the preferences of those entities. Market failure does exist in the areas of compressed air and electric motors however, largely because of poor information.

Appropriate ways of addressing these information gaps differ between compressed air and electric motors. This is partly because the main efficiency opportunity for motors occurs at failure time which is essentially random, whereas for compressed air efficiencies can be secured at any time. In addition, there is a single clearly identifiable action required to improve motor efficiency (upgrade to a new motor), whereas the solutions for compressed air systems may arise in many different parts of the system and therefore need to be addressed in different and site specific ways.

Compressed Air

For compressed air systems, we evaluate the most developed intervention proposal, which is an audit programme funded by the Electricity Commission. There is substantial international evidence that a programme of this nature would save around 15% of the electricity used in CAS installations. This estimate is broadly consistent with the findings of a pilot study conducted for the Electricity Commission.

Based on the 15% savings assumption, the audit costs per kWh of electricity saved is shown in Table 1, broken down by size of CAS installation. Firms will also bear costs to implement recommendations, and the Electricity Commission will also incur costs to initiate and run the programme. These added costs may be several times higher than those of the audit itself. Nevertheless, Table 1 shows that there is clear economic merit in auditing the largest four categories of CAS sites. Smaller users of compressed air (category 6 and possibly also category 5) will need to be reached in some other manner, possibly by methods similar to those proposed for electric motors. The cost of an audit programme for categories 1 to 4 inclusive is around $1.2m plus the Commission's costs for training, developing materials and monitoring the audit reports. It is anticipated to save 180GWh per year.

Table 1 CAS audit cost per unit of electricity saved

Size Category	Savings (GWh/yr)	Total Cost	Unit Cost ($/kWh)
1 (largest)	18.0	$ 40,000	$ 0.002
2	21.6	$ 96,000	$ 0.004
3	72.0	$ 480,000	$ 0.007
4	67.5	$ 608,000	$ 0.009
5	30.0	$ 800,000	$ 0.027
6 (smallest)	15.0	$ 4,000,000	$ 0.267

To be effective, a CAS audit programme will need to capture the attention of firms at the highest level (ie the CEO) and secure a commitment to implementing the recommendations of the auditors. Additionally, the Commission needs to ensure that auditors (who are likely to be drawn from the compressor supply industry, at least in the first instance) are properly trained monitored.

Electric Motors

The main opportunity for securing greater efficiency from electric motors is through upgrading of the quality of the installed base of motors. This requires a change in current practices: replacement with a new motor rather than rewinding the existing motor. Since motors fail at different times, upgrading will be a gradual process spread over up to 20 years (the estimated service life of the largest relevant motors).

Drawing on previous analysis, we estimate the technically achievable savings through motor upgrades. If all motor failures were addressed through replacement, total motor load would be around 220 GWh per annum lower after 10 years, falling to around 165 GWh per annum lower after 20 years and less thereafter. We do not consider that 100% replacement is likely, and have instead assumed that 60% of the performance gap could be closed by a well framed intervention (implying that an intervention would not result in all failed motors being replaced). Views on the effectiveness of interventions will obviously differ; more aggressive schemes will generate greater savings. Under our working assumption of 60% effectiveness, the associated savings over time are shown in Figure 1.

From the perspective of a firm, replacing a motor is a capital investment whereas rewinding is a current expense. There are several ways of framing the investment decision, but all require assumptions about the discount rate acceptable to the investor. As a result, the net benefit of replacement varies across firms. Additionally, the size of motor makes a difference to the financial attraction of replacement. Our analysis uses three motor sizes, each of which is towards the centre of three larger categories of motor size used in previous analysis.

Table 2 shows the estimated net annual benefit from replacement for two types of firms, and for society as a whole. All net benefits are positive, which indicates that replacement of motors is actually profitable for firms.

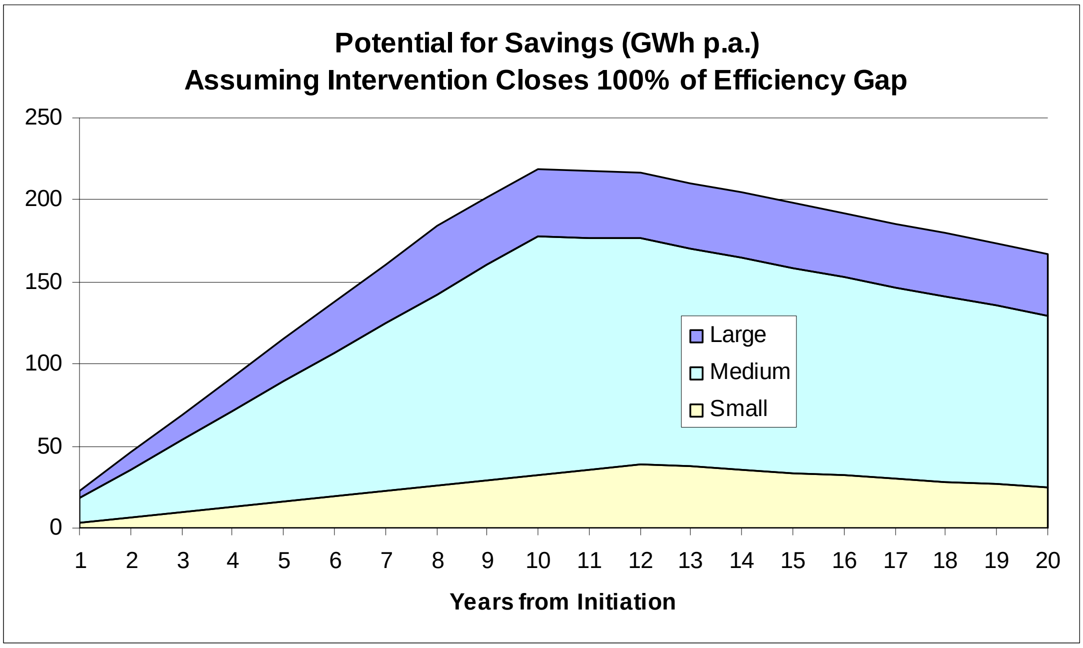

Figure 1 Potential electricity savings through increasing replacement rates for electric motors

Even though replacement is profitable, more than half of failing motors are rewound rather than replaced. The proposed intervention would enlist the assistance of rewinders and other industry professionals, and seek to spread greater awareness of the benefits of replacement.

Table 2: Net annual benefit from replacement compared with rewinding.

	Motor Sizes		
	4	30	90
Firm - 25% discount rate	$90.31	$413.74	$587.53
Firm - 10% discount rate	$94.44	$556.12	$971.53
Society	$50.20	$235.42	$319.10

The precise details of the motors intervention are still being worked out. We expect that it will not be particularly costly for the Commission however, as it is primarily intended to supply information.

1. Introduction

The Electricity Commission is obliged to promote and facilitate electricity efficiency and conservation. Recognising the potential for greater overall efficiency in resource use, it is particularly interested in situations where efficiency and conservation have the potential to be more cost effective than building new supply-side assets.

As part of this line of work, the Commission has recently concluded separate technical investigations into the efficiency and conservation potential of two commercial uses of electricity: motors, and compressed air. The close relationship between these uses has also been recognised: compressed air systems are frequently powered by electric motors.

Now that these investigations are complete, it is necessary to consider the actions that might be taken by the Commission. A range of intervention options are available to the Commission, both directly and through its relationships with other agencies. The task at hand is to assess these options using the disciplines of public sector economics. The objective of this report to determine whether, and if so by how much, a particular intervention is likely to create additional value.

We start by analysing the existence or otherwise of market failures in section 2. Interventions that have been proposed in respect of compressed air systems and electric motors are considered in sections 3 and 4 respectively. Those interventions are evaluated in 5, which is followed by a brief conclusion.

2. Market Failure

The Electricity Commission is funded through a levy on the electricity industry, which is ultimately paid for by consumers. Its investments therefore effectively use public funds, and should be evaluated using an appropriately disciplined process. An important step in that process is to determine whether a market failure exists: ie, whether there are grounds for believing that commercial trading in markets will not result in socially efficient outcomes.[1]

It is often observed that electricity efficiency measures do not receive high priority from end-users, especially where the electricity is used as a production input. For example, some of the analysis reported in section 5 below shows that the private benefits of particular efficiency measures exceeds private costs. The same conclusion was reached by Energy Associates who undertook earlier work for the Electricity Commission on these topics.

That observation however, does not necessarily imply anything about market failure. It may be entirely a reflection of personal preferences, in which case some would argue that there is no market failure. Alternatively, it may be that the relevant markets are not allocating resources efficiently because decision makers are not fully informed; if people were better informed, different conduct would arguably be observed. On that view, the existing markets are failing to provide sufficient information.

Consumer preferences are a fundamental building block of microeconomic theory, but they are clearly not fixed over time. If they were, a significant amount of effort directed at changing the preferences of consumers would be wasted. Advertising, in-store promotions and a range of special offers are used to simultaneously inform and persuade consumers to make new choices.

Electricity suppliers in New Zealand are active users of these methods. Their advertising is largely aimed at building a positive view of their own company in the minds of end-users, rather than promoting electricity use *per-se*. However its presence does indicate that the market for electricity supply is reasonably well developed.

By contrast, it would be difficult to argue that there is a market for electricity efficiency in New Zealand. There are companies that assist with managing procurement costs, essentially by comparing prices across retailers, in return for a share of the savings. But there are no significant providers who will audit plants on the same remuneration basis.

As a result, information and persuasion on electricity efficiency issues is either not supplied at all, or is under-supplied relative to what would be observed if markets were complete and well functioning. Activity that can be shown to produce value is not being supplied. In our view, this is a market failure.

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[1] If there is a market failure, one additionally needs to establish that the proposed public intervention will produce benefits that exceed its costs. That step of the process is analysed in section 5.

2.1. Compressed Air

There is strong evidence (discussed in section 3.2) that firms do actually under-invest in the efficiency of their compressed air systems. That is, profitable investments are not undertaken. Since firms are "leaving money on the table" in this way, it is natural and appropriate to seek the explanation for that conduct within the firms themselves. Several reasons have been cited for a lack of private investment in profitable measures related to compressed air. A recent German study identifies the following:[2]

- Motor system electricity consumption is largely invisible to top management because it is a small component of total cost;
- It is often treated as an overhead so no single person is responsible for managing its level;
- Reinforcing the previous item, demand management touches several different areas of responsibility (eg production, finance, maintenance) so it is difficult to co-ordinate efficiency initiatives; and
- Price competition over electricity-using assets tends to focus on initial cash outlays rather than life-cycle costs, so efficiency is under-valued.

These are very plausible explanations, all of which arise from the way companies are organised. Internal structures of this type tend to be optimised with regard to the revenue and cost items that are largest and most easily managed. This will include electricity costs for some firms (eg major energy users such as the aluminium smelter), but where electricity costs are not a major share of total cost efficiency will have a correspondingly lower priority.

Information from other countries lends support to the view that conduct would change if firms were better informed. The production and dissemination of best practice guides occurs in several other jurisdictions, and there is also evidence of significant energy savings being achieved following the use of such materials.[3] This suggests that firm conduct does change in response to better information, in which case a market failure does exist.

2.2. Electric Motors

Previous work for the Electricity Commission has addressed the potential for efficiency gains arising from better practices regarding the industrial use of electric motors. Motor replacement, commissioning and maintenance were studied and a range of possible interventions proposed. A major conclusion was that efficiency could be improved by replacing rather than rewinding electric motors when they fail.

The question at hand is whether the markets in which electric motors are acquired, commissioned and maintained are allocating resources efficiently. Our evaluative analysis (section 5.2) suggests that there is a reasonably strong desktop business case for

[2] http://www.isi.fhg.de/publ/downloads/isi01b04/compressed-air-long.pdf

[3] http://www.compressedairchallenge.org/content/library/casestudies.cfm

replacing rather than rewinding many electric motors when they fail. Yet the earlier analysis found that rewinding is still very common.

The co-existence of these two facts tells us that firms are not behaving in a purely rational manner: opportunities for profitable investment in new motors are being foregone. The previous analysis effectively concluded that there the reasons for this fall broadly into two categories.

- Organisational issues within firms, which focus managerial attention on the revenue side of the business and on the larger components of total cost. These are similar to the issues discussed in section 2.1.
- Supply chain issues, notably the fact that rewinders are also the major suppliers of new motors to the motor users.

The first of these seems very plausible. If firms could improve their net income but do not, there are likely to be internal reasons for that. The alleged preference for motor vendors to favour the rewind aspect of their business is rather less obvious and would benefit from closer investigation. For it to be a rational contributor to the lack of uptake of new motors, there would need to be greater return to rewinding than to the sale of new motors. That could be so, but has not been established so far.

Competition provides another motivation for rewinders to emphasise repair over replacement. Rewinders clearly require a deeper knowledge of electric motors than retailers. Emphasising this attribute therefore gives such firms an opportunity to differentiate themselves from a pure retailer, potentially making them more of a trusted partner than a mere supplier of equipment.

Additionally, differential tax treatment between repairs and replacement of motors does tend to bias decisions in favour of repair. Repairs are fully deductible from current income, whereas replacements are treated as capital and depreciated slowly over time. It is not clear whether that influence is decisive, but its existence is a form of failure that potentially justifies intervention.

3. Compressed Air Interventions

This section provides brief introductions to the electricity efficiency issues arising from compressed air systems, and then describes the interventions that will be analysed in section 5.

Compressed air has a wide variety of industrial uses, and is generally reticulated through a plant. It is often referred to as the fourth utility, after electricity, gas and water. The compressed air systems (CAS) often use more electricity than any other type of equipment, so it is important that their performance is optimised. This requires attention to both "sides" of the system: the supply side, comprising all of the compressors, motors and treatment facilities; and the demand side where the delivered air is used.

Each of the main elements on the supply side of a CAS need to be considered when optimising performance. They are:

- Compressors;
- Energy sources (eg electric motors);
- Controls;
- Treatment equipment; and
- The distribution system including storage tanks.

Since the components of a CAS are dimensioned to accommodate peak loads, it will generally be inefficient to operate the system in a 'binary' (ie on-off) manner. Controls that regulate system output, including through throttle valves within the distribution system and via variable speed drives on electric motors, can help to better match the production and delivery of compressed air with demand for it.

The components themselves also need to be selected with demand in mind. There are many different types and sizes of compressor, and some are more suitable than others for particular uses. For example, a centrifugal compressor is well suited to providing "base load" air while positive displacement compressors follow the load. Similarly, the types and sizes of electric motors can make a significant difference to overall system efficiency.

Storage tanks allow a CAS to partially disconnect the timing of air production and use, which can improve system performance. Tanks are likely to be more valuable in systems where the load is more variable. They can potentially play a "peak shaving" role, which allows smaller compressors to be used elsewhere in the system.

Alongside these system design and component selection issues, the operation of the CAS can also benefit from attention. Efficient maintenance schedules should include periodic replacement of filters and fluids, adjustment of drive belts, and the tracking and rectification of leaks.

With so many distinct elements involved, and overall performance being to some degree dictated by the "weakest" link, optimisation of a CAS needs to be undertaken on a system-wide basis. The following steps are likely to be part of that process:[4]

- Establishing current conditions and operating parameters
- Determining present and future process production needs
- Gathering and analyzing operating data and developing load duty cycles
- Analyzing alternative system designs and improvements
- Determining the most technically and economically sound options, taking into consideration all of the sub-systems
- Implementing those options
- Analyzing operations and energy consumption and analyzing economics (i.e., validating performance)
- Continuing to monitor and optimize the system
- Continuing to operate and maintain the system for peak performance.

It is also important to recognise that compressed air is not always the best way of achieving desired outcomes in industrial processes. Alternative technology, such as vacuum swing pressure adsorption (VSPA) can sometimes achieve the same or better results at considerably lower energy cost.[5]

3.1. Possible Interventions

Drawing on previous analysis, it was argued above (section 2.1) that the main barriers to more efficient CAS management are organisational ones: they exist entirely within firms and derive from the way they are arranged. It follows that interventions should be targeted at removing or lowering these barriers.

The required changes are to ongoing processes rather than once-only decisions. There are two main reasons for this. One is that maintenance is of critical importance in securing and sustaining efficiency gains. Secondly, industrial plants are often reconfigured to accommodate changes in production requirements. If changes are made to the CAS, it will generally need to be set up again in an efficient configuration.

3.1.1. Subsidised Audit Programme

A specific intervention proposal has been developed though previous work supported by the Electricity Commission. The following outline is indicative:

- A team of CAS auditors would be certified by the Electricity Commission;
- Auditors would inspect the CAS of target firms, and report clear recommendations jointly to the firm and the Commission;
- Firms would implement the recommendations at their own cost;
- Some form of monitoring would be used to check outcomes.

[4] US Department of Energy, Compressed Air Challenge, Compressed Air SourceBook, p 17.

[5] http://www.nyserda.org/Press_Releases/press_archives/2002/04_25_02.asp

This proposal could be adjusted in several ways that remain to be determined. It will obviously be important to gain a high level commitment to follow-up action from the firm, and there are a range of ways that could be achieved.

3.1.2. Regulatory Alternative

Rather than assisting firms through the provision of free auditing services, one might consider imposing upon them then obligation to obtain and pay for their own audit. Using a car analogy, the subsidised process outlined above is similar to making warrant of fitness inspections free, whereas the regulatory alternative is similar to the existing arrangement for warrants of fitness.

3.1.3. Auditor Issues

Compressed air audits are currently supplied by compressor distributors. These firms are more likely than others to have the necessary technical knowledge, and are therefore an obvious source of the pool of expertise the Commission would need to deploy this intervention. However they also have conflicting objectives to some extent, since their main line of business is selling and servicing equipment.

We believe that this conflict is manageable, but it does require that careful attention be given to the screening/accreditation process for auditors, and to the drafting of reporting guidelines. Accreditation will almost certainly be used by auditors as a signal of quality to potential purchasers of audit services. For example, if a specific logo is attached to accreditation, it will probably be used for advertising purposes in the same way that builders use their affiliation to the Master Builders Federation.

It is important to ensure that auditors are themselves subject to the potential for disciplinary action, including the loss of accreditation status. That threat should be backed by, and known to be backed by, a review process during which auditor reports are screened for abnormalities. Comparisons across auditors for similar types of sites should help to ensure that anomalies are noticed in a timely manner.

3.1.4. Sustainability

It is important that savings achieved through CAS audits and follow-up action are sustained, ideally by the firm itself. To the extent this outcome is achieved, the cost of the audit will generate an ongoing flow of efficiencies, increasing the pay-off to public investment. It is clear that the Electricity Commission is aware of this issue and has reasonably well advanced plans to promote the sustainability of savings.

3.2. Potential for efficiency gains

Energy is by far the largest component of the total cost of air compressors. Figure 2 shows a breakdown of costs sourced from the British Compressed Air Society (BCAS),[6] which estimates that 73% of total costs are for energy. Notice also that maintenance, which is critical to managing energy costs, is only around 7% of total cost.

The compressed air sourcebook (footnote 4) suggests that there is significant potential for energy savings in the way compressed air is managed:

> "…Most compressed air systems use considerably more energy than is needed to support the demand. Compressed air systems usually have a wire-to-work[7] efficiency of around 10 percent, which is very low. In many cases, after a thorough review of a compressed air system and after corrective actions are taken, one or more of the compressors may be shut off and the overall system efficiency improved. …"

The proposition that substantial savings can be made is consistent with the results of a pilot study undertaken at Fonterra's Te Rapa plant by Demand Response Ltd in 2006. That study reported that electricity savings of 32% were achieved through:

- Air leakage management;
- Shedding peak air demand and inappropriate air use;
- Improved compressor control; and
- Reduction of CAS operating pressure.

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[6] http://www.bcas.org.uk/pdf/carbontrust/GPG385.pdf

[7] This refers to the conversion of delivered electricity (through the wire) into the potential energy that can be released from the compressed air.

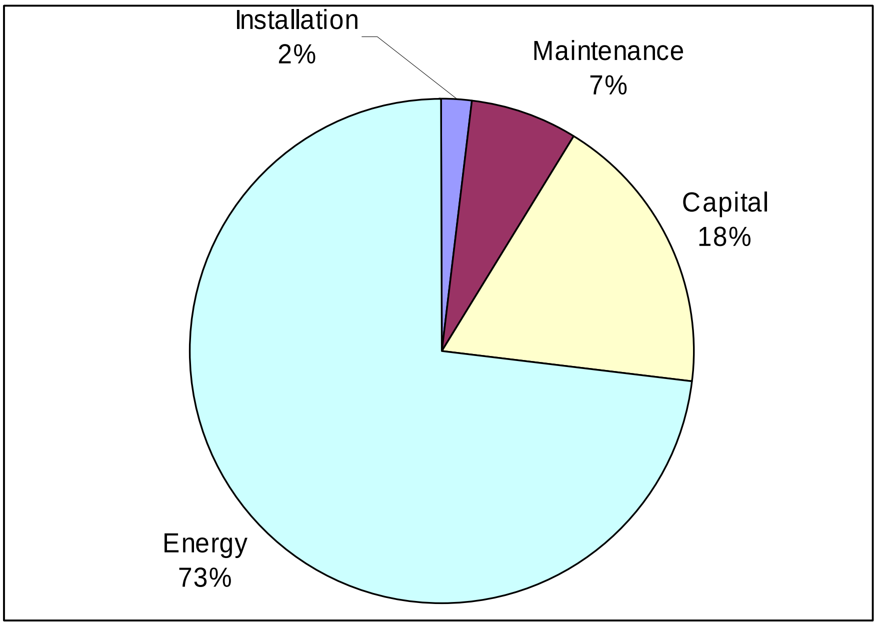

Figure 2 Cost components for air compressors over 10 year life (source: BCAS)

These findings can be evaluated against international modelling, notably that reported by Radgen and Blaustein (eds) (2001).[8] This detailed study modelled total CAS electricity demand in the EU under three intervention scenarios defined as:

- Business as usual (BAU), where no interventions occurred;
- Awareness raising programme (ARP); and
- Economic and regulatory programme (ERP), which included specific regulations and direct subsidies for equipment.

This work was careful to distinguish between technical efficiency potential and the economically achievable outcomes, which tend to be substantially lower. A summary of the modelling results is presented in Figure 3.

[8] P. Radgen and E. Blaustein (eds) Compressed Air Systems in the European Union: Energy, Emissions, Savings Potential and Policy Actions, 2001, LOG_X Verlag GmbH, Stuttgart, available online at http://www.isi.fhg.de/publ/downloads/isi01b04/compressed-air-long.pdf

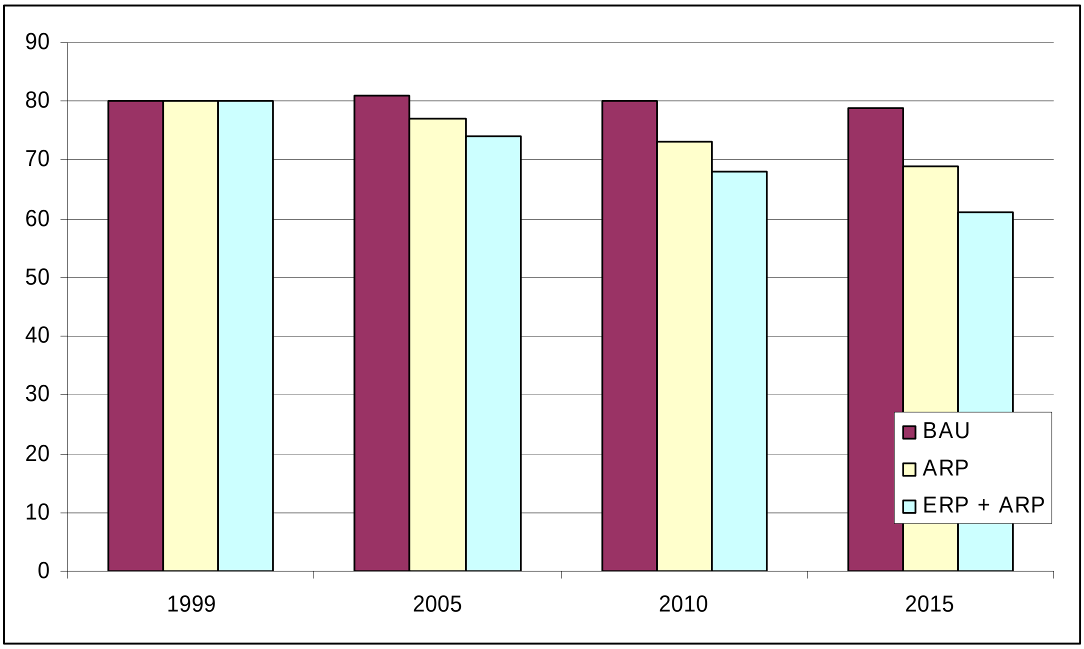

Figure 3 Total CAS electricity use (TWh) in EU by intervention scenario (source: CAS in the EU)

The data underlying Figure 3 show that in percentage terms, the ARP scenario was expected to achieve savings of 5%, 9% and 13% relative to BAU in years 4, 9, and 13 of the programme. The corresponding figures for the ERP scenario were 9%, 15% and 23% of BAU demand.

Further evidence on the potential electricity savings from CAS efficiency is found in the British Compressed Air Society's Good Practice Guide (see footnote 6) from which the information in Table 3 was sourced. Some of these figures are cumulative (eg purchasing policy + leak repair programme), but results will vary across systems. The estimates are based on a 7 bar system producing 500 liters/sec. Costs denoted as "low" are estimated at less than £2,000, while "medium" costs are in the £2,000—£10,000 range.

Table 3 Savings achievable by action category (Source: BCAS)

Actions	Savings	Cost
Management Actions		
Raise the awareness of all users to the proper use of compressed air	10-15%	Low
Develop and implement a maintenance programme for the whole system	5-8%	Low
Install metering and implement monitoring	5-10%	Medium
Use only trained and competent personnel for installation, servicing and upgrades	5-10%	Low
Develop and implement a purchasing policy	3-5%	Low
Technical Actions		
Implement a leak reporting and repair programme	20-40%	Low
Do not pressurise the system during non-productive periods	2-10%	Low
Fit dryer controls (refrigerant and desiccant)	5-20%	Medium
Install compressor drive and system control measures	5-15%	Medium
Install heat recovery measures where appropriate	Up to 75%	Medium

The above evidence suggests that around 15% of CAS electricity could be saved through improved practices. This is consistent with the view of those involved in the design of CAS interventions in New Zealand.

The size of the local market for electricity supplied to CAS applications has been estimated in previous work by the Electricity Commission. It is presented in Table 4 and shows that a significant proportion of all use is concentrated in a relatively small number of sites. That is, sites with in excess of 500kW of installed capacity (ie categories 1 to 3 inclusive) account for 49% of electricity demand for CAS, but are less than 2% of sites.

Table 4 CAS Electricity use in New Zealand, by user type (Source: Electricity Commission)

Category	Installed demand (kW)	Number of sites	Total demand (MW)	Total use (GWh/y)
1	>1,500	5	15	120
2	1,000 - 1,500	15	18	144
3	500 – 1,000	100	75	450
4	75 - 500	380	57	342
5	25 - 75	1,000	50	200
6	<25	5,000	50	150

If the targeted savings level (15%) could be achieved for just this relatively small group of large users, annual savings of 107 GWh would result.

4. Electric Motor Interventions

Previous work for the Electricity Commission has addressed the potential for efficiency gains arising from better practices regarding the industrial use of electric motors.[9] [10] Motor replacement, commissioning and maintenance were studied and a range of possible interventions proposed. Those recommendations provide the starting point for our analysis.

4.1. Possible Interventions

4.1.1. Replacement

New Zealand recently (2006) introduced new Minimum Energy Performance Standards (MEPS) for electric motors, upgrading the standard from the first version introduced in 2002. This innovation creates a significant gap in efficiency between old installed motors and new replacement motors. However it appears that when motors fail, firms are more inclined to rewind their existing motors rather than replace them with new and more efficient ones. This tendency is said to be reinforced by the fact that motor rewinders are also the main vendors of new motors.

The business case for rewinding versus replacement is considered in section 5. At this point we outline the method that has been proposed as a way of shifting preferences away from rewinds and towards replacement. The proposal focuses on the motor rewind sector as a channel to change market practices and involves the following actions:

- Assist rewinders to build capacity to:
  - evaluate present in-service motor stocks
  - rationalise stored motors and remove inefficient motors from service
  - administer replacement policies; and
- Develop and provide motor management tools to facilitate roll-out of site policies and motor store rationalisation.

These are relatively low cost and non-intrusive measures. They do not involve subsidising the replacement of motors, but are instead aimed at providing better information so that firms and rewinders are more likely to upgrade to more efficient motors.

4.1.2. Commissioning and Maintenance

Earlier analysis by EA (footnote 9) has suggested that substantial electricity savings are available from better attention to the commissioning and maintenance of electric motors, and that this could also provide firms with significant co-benefits in the form of reduced

[9] Industrial Motors Efficiency Pilot Project, Final Report 4: Motor System Commissioning and Maintenance, by Energy Associates Ltd, for Electricity Commission, October 2006.

[10] Industrial Motors Efficiency Pilot Project, Final Report 2: Motor Replacement, by Energy Associates Ltd, for Electricity Commission, October 2006.

down time. Commissioning issues include selecting the appropriate size of motor, alignment of the drive train, and belt tension. Maintenance includes lubrication and re-tensioning of belts.

The potential scale of the electricity savings available was drawn from international third party sources by EA and was reported as amounting to between 3% and 10% of power used.

The report recommended that the Electricity Commission work with key players in the maintenance industry to build an effective strategy improving commissioning and maintenance practices. It argued that the key to obtaining savings was cultural change within the user community, and that this would occur when users saw the potential benefits of improved maintenance. Specifically, it proposed that the Commission:

- Develop a consultative group in the maintenance sector and work with them to further develop options for improving industrial maintenance, including programme options for:
    - improving management awareness of broad benefits of robust maintenance
    - improving access to, and the quality of, training resources for industrial trades staff
- Promote wider use of a self assessment tool as a means of targeting businesses for possible intervention and to raise awareness.
- Provide a range of Web-based guides or resources targeted at those that are motivated to take action, or actively pursuing improvement. Examples could include a belt tensioning guide and a lubrication guide.

4.2. Potential for Efficiency Gains

Our estimates of the potential electricity savings from electric motor interventions is based on replacing rather than rewinding motors. We use information previously developed by Energy Associates ('EA', footnote 10) who estimated the total load of small, medium and large electric motors. EA also supplied mean failure times and estimates of the additional efficiency from replacing rather than rewinding motors.

Table 5 shows our estimates of the technical potential for savings. There are three key inputs into these calculations:

- EA's estimate of the efficiency difference between existing and MEPS motors;
- The total electrical load of electric motors in the year to March 2004; and
- EA's estimate of the mean time to failure for electric motors.

The technical potential estimates assume that motors are replaced as they fail. EA provide high, medium and low scenarios; we use the medium scenario for our analysis where small motors fail after 12 years on average, medium motors 10 years and large motors 8 years. It will therefore take 12 years to realise all potential savings from replacing these motors.

Table 5 Technical potential for savings by replacing rather than rewinding motors

	Technical Potential for Savings (GWh per annum)		
Year	Small Motors	Medium Motors	Large Motors
1	5	19	6
2	10	37	11
3	15	56	17
4	20	75	22
5	25	93	28
6	30	112	33
7	35	131	39
8	40	149	44
9	45	168	44
10	50	186	44
11	55	186	44
12	60	186	44
13	60	186	44
14	60	186	44
15	60	186	44
16	60	186	44
17	60	186	44
18	60	186	44
19	60	186	44
20	60	186	44

Table 5 shows that a total of 290 GWh per annum could be saved after 12 years by replacing rather than rewinding failed motors. A significant proportion of this technical potential will be realised with no intervention. EA estimate, under a medium scenario[11], that 35%, 22% and 6% of small, medium and large motors respectively are already being replaced rather than rewound at failure time. Even if an intervention was able to completely eliminate rewinding, it would only secure around 3/4 of the savings shown in Table 5 in the years of peak savings[12] and less thereafter; the other savings will happen anyway provided existing patterns of behaviour persist. The maximum savings an intervention could yield is 220 GWh per annum after 10 years, declining thereafter.

The precise details of an intervention aimed at inducing a higher rate of replacement rather than rewinding are not formed at this stage. In these circumstances, we believe it is prudent to adopt a conservative view of the potential savings available through such a strategy. Our working assumption is that between 40% and 60% of the achievable savings might be secured[13]. Figure 4 shows savings in each of the next 20 years, assuming that 60% of the efficiency gap is closed by intervention. This assumption yields a peak of 130 GWh per annum saved.

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[11] The current proportions of failed motors being replaced were taken from a note by EA sent to the Electricity Commission. The medium scenario was not described in detail in the original EA report.

[12] Potential savings from an intervention peak after 10 years, at 78% of technical potential savings. This amount then falls as technical potential savings are completely realised after 12 years, while actual savings realised with no intervention continue increasing for many years as motors slowly get replaced under a business-as-usual scenario.

[13] As specific intervention details are not yet formed, it is unclear how reasonable this assumption is.

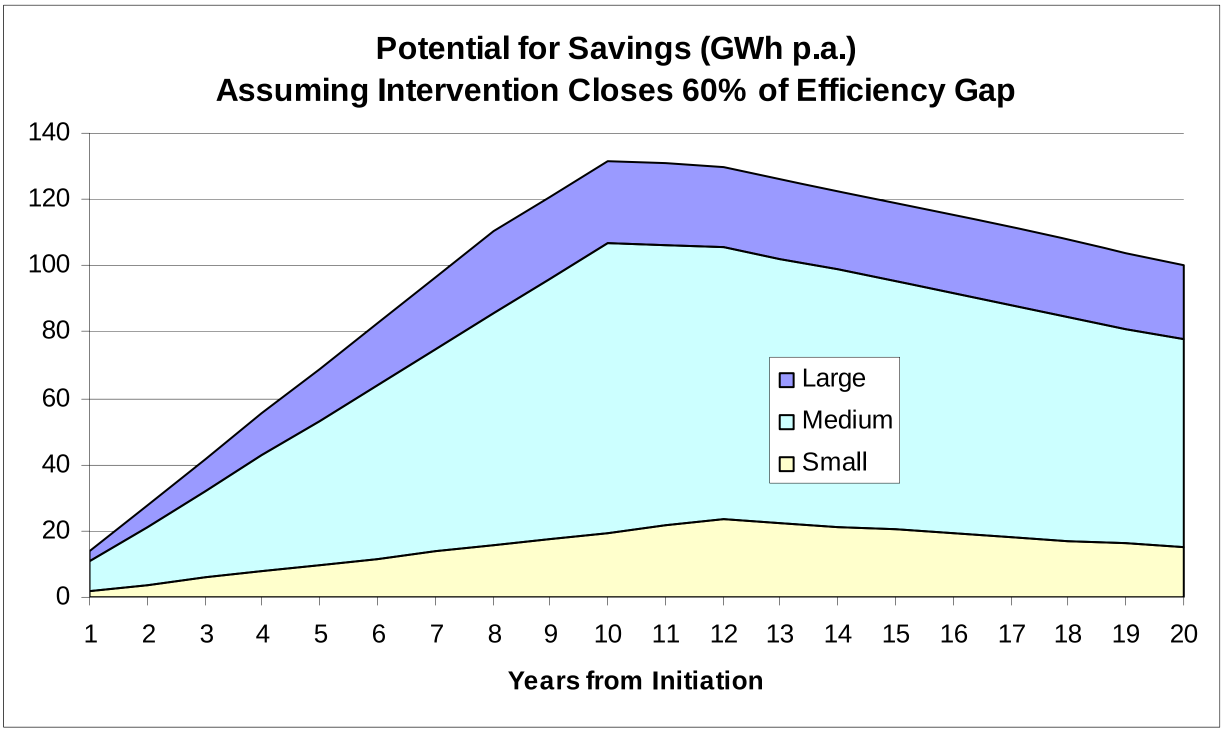

Figure 4 Potential Savings from Motors Intervention

To put these figures into perspective, the efficiency benefit available by changing current practices rises to a peak of around 220,000MWh per annum after 10 years, falling thereafter. If an intervention could secure 60% of this benefit, that would avoid the need for 27MW of generation capacity (assuming that the plant was operated for 50% of the year).

5. Evaluation

It has been established that there is potential for greater electricity efficiency within compressed air systems and the purchasing, installation and maintenance of electric motors. Specific proposals for securing these efficiency gains have been discussed. The objective of this section is to evaluate those proposals.

We focus only on those interventions for which the costs and yields are reasonably predictable. They are an auditing programme for compressed air systems and promotion of a replacement programme for electric motors. It has not been possible to provide the same level of analysis for programmes aimed at improving commissioning and maintenance practices for electric motors.

5.1. Compressed Air Systems

The cost of a single CAS audit is largely determined by the labour requirement. We have estimated this requirement using information supplied by a member of the original project team, combined with scaling assumptions to allow for variation by the size of the CAS on each site. Using $100/hr as a labour rate, Table 6 shows the estimated cost by size of system and Table 7 shows the unit costs of electricity saved as a result of audits.

Table 6 Cost of audits

Category	Person days/site	Number of sites	Cost
1	10	5	$ 40,000
2	8	15	$ 96,000
3	6	100	$ 480,000
4	2	380	$ 608,000
5	1	1,000	$ 800,000
6	1	5,000	$ 4,000,000
Total		**6,500**	**$ 6,024,000**

It is expected (section 3.2) that successful implementation of the recommendations of an audit will yield savings of 15% of total CAS electricity use. If these assumptions are approximately correct, then saving electricity in this manner is very cost efficient, except for very small sites.

Table 7 CAS audit cost per unit of electricity saved

Category	Savings (GWh/yr)	Total Cost	Unit Cost ($/kWh)
1	18.0	$ 40,000	$ 0.002
2	21.6	$ 96,000	$ 0.004
3	72.0	$ 480,000	$ 0.007
4	67.5	$ 608,000	$ 0.009
5	30.0	$ 800,000	$ 0.027
6	15.0	$ 4,000,000	$ 0.267

The Electricity Commission would also incur costs to establish and operate the scheme. They would include the development of training materials and reporting systems, and ongoing administration costs.

Further costs would be borne by firms as they implement the auditors recommendations. Based on the technical reference material, many of these would also be labour costs, for such things as detecting and repairing leaks, and setting up banks of compressors so that they share the load efficiently. In principle, a publicly funded audit should only occur where there is a reasonable expectation that the total cost of savings (ie including the costs borne by the firm) are less than the value of saved electricity. Unfortunately, we have no reliable information on the costs firms would incur under this proposal.

A reasonable way to proceed is to assume that, since these non-audit costs are largely labour related, they could be proxied by some multiple of audit costs. Category 1 and 2 sites would yield short-run savings worth more than costs if that multiple was up to 30 and 15 respectively. For category 3 and 4 sites, non-audit costs could be around 11 and 8 times the cost of the audit and still result in net benefits, even in the short-run. We conclude that for these four categories of user, there are very likely to be positive net benefits from the proposed course of action.

The situation is considerably more tenuous for category 5 and 6 CAS installations. There is no business case for auditing category 6 sites, because the costs (40c/kWh) are materially higher than the value of energy that can be expected to be saved. Similar, though somewhat weaker, conclusions apply to category 5.

5.1.1. Implementation Issues

While the above analysis suggests that there is a good case for the Commission to fund a CAS auditing programme, several additional matters need to be addressed to ensure that any funds so committed will be effective. Two issues are particularly important:

- Firms must commit to following through on audit recommendations; and
- Auditors must be properly trained and monitored.

The commitment of a firm can ultimately only be made by its chief executive. Unless this person understands and supports the objectives of the programme, there is no point in conducting an audit. The written endorsement of the CEO therefore seems a reasonable pre-condition to providing an audit. It would also be valuable to obtain pre-approval for auditors to make a follow-up visit (eg six months later) to check that recommendations have been implemented. At that point the firm could be awarded some kind of recognition such as an energy saver star.

We have some concerns about the availability of a pool of suitably trained auditors. It seems likely that the relevant skills are mainly located within firms that supply air compressors. This raises the potential for a conflict of interest by auditors. To help manage that risk, it would be useful for the Electricity Commission to

- design a standard reporting template;
- prepare guidelines for its use;
- receive a copy of all audit reports; and

- compare recommendations across auditors with a view to identifying any tendency to over-prescribe (eg to make unwarranted recommends about the replacement of equipment).

5.2. Electric Motor Replacement

When electric motors fail, they can either be replaced or rewound. Replacing a motor may have a greater up-front cost then rewinding. All new motors must meet New Zealand's Minimum Energy Performance Standards (MEPS) while old motors generally don't meet these standards. However, MEPS compliant motors are more energy efficient than older motors, and hence there are ongoing cost savings to be gained from replacement. If these savings outweigh the higher capital cost, then it is economic to replace as opposed to repair. The net benefit is generally different for society than it is for an individual firm.

Following Energy Associates' analysis, we have considered three-phase induction motors in three separate groups, based on size: 0.73-7.5kW, 7.5-75kW, and 75-185kW. We have considered the particular motor sizes near the middle of each size range. We surveyed several rewinders by phone and obtained quotes for rewinding and replacing motors in each of these categories. The raw data is shown in Table 8.

Table 8 Raw data on replacement and rewinding costs (excl GST)

Size	Replacement Cost ($)	Rewind Cost ($)
4kW	400	472
	460	700
	550	650
25kW	2500	1600
30kW	2290	2100
	2200	
	3800	2300
88kW	6000	3500
90kW	6000	3500

The following analysis uses averages of these observations to represent rewind and replacement costs. We have converted capital costs into per annum figures using an annuity formula. Using an assumed useful life[14] and a discount rate, we can obtain the annual cost implied by the total capital cost. Because the tax benefits of each option accrue in different years (immediately for rewind, over the useful life as the motor is depreciated for replacement), this must be compensated for – tax benefits from replacement are discounted. Annual costs calculated represent after-tax values (see Appendix A for an explanation of how this is done). We have used a discount rate of 7%

[14] We have used Energy Associates' Scenario B, of 12, 10 and 8 years for small, medium and large motors. Energy Associates also suggested shorter and longer scenarios, which we modelled. These other scenarios give broadly similar results, but the benefit from replacement increases with the useful life.

for society, and 10% and 25% for an individual firm[15]. Table 9 outlines the costs of replacement.

Table 9: Cost of replacement compared with rewinding.

	Motor Sizes		
	4kW	30kW	90kW
Cost of replacement motor ($)	470	2,698	6,000
Cost to rewind existing motor ($)	607	2,000	3,500
Useful life (before next rewind)	12	10	8
Extra capital cost of replacement	-137	698	2,500
Extra cost per year of replacement			
Firm - 25% discount rate	-1.42	270.79	841.05
Firm - 10% discount rate	-5.55	128.41	457.05
Society - 7% discount rate	-6.05	104.57	390.46

It is worth noting that for small motors, the cost of rewinding is greater than the price of a new motor[16]. So it is economic to replace small motors even before considering the ongoing efficiency savings.

The benefit of replacing a failed motor is that a new MEPS compliant motor will be more efficient than the existing motor. A lower amount of energy losses translates into an ongoing cost saving each year. We have used the figures for efficiency gains quoted in the Energy Associates report, ranging from 8.4% for an average small motor to 4% for a large motor.[17]

We have assumed an average load factor of 60% for all sizes of motor, and utilisation rates of between one third and one half. The declining useful life as motor size increases is generally the result of increasing operational hours. So our assumptions imply small motors are used for 8 hours a day, every day, while medium-sized motors are used for 10 hours and large motors 12 hours. Using this loading, and the average capacity for each size of motor, we obtained the kWh usage per year. Applying the efficiency gains to these usage values, we calculated the kWh savings per year. We then valued those savings at 7.5 cents/kWh in the short run and 15.1cents/kWh over the long run (see appendix B). These calculations are shown in Table 10.

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[15] Society generally has a lower discount rate than individuals, because society is more forward looking. In practice, firms are often considered to have quite high discount rates, reflecting management's desire for short payback periods.

[16] Despite quite a sizeable difference in one-off costs, this is almost offset by the tax benefit of rewinding accruing immediately.

[17] These are percentages of total power which can now be harnessed when they were previously wasted.

Table 10: Benefit from replacement compared to rewinding a motor.

	Motor Size (kW)		
	4	30	90
Efficiency gain (%)	8.40%	6.90%	4%
Average motor loading	60%	60%	60%
Length of time used (h/day)	8.00	10.00	12.00
Current usage (kWh p.a.)	7,008	65,700	236,520
Savings (kWh p.a.)	589	4,533	9,461
Value of savings ($ p.a.)			
Short run	$44.15	$340.00	$709.56
Long run	$88.89	$684.53	$1,428,58

If the benefits outlined in Table 10 are greater than the costs in Table 9, then it is economic to replace a failed motor instead of rewinding it. Subtracting the per annum cost from the annual savings gives the annual net benefit from replacement. These results are shown in Table 11.

Table 11: Net annual benefit from replacement compared with rewinding.

	Motor Sizes		
	4	30	90
Firm - 25% discount rate	$90.31	$413.74	$587.53
Firm - 10% discount rate	$94.44	$556.12	$971.53
Society	$50.20	$235.42	$319.10

The firms' benefits in Table 11 are calculated with reference to long-run values of savings, which are very similar to retail electricity costs.

5.2.1. Implementation Issues

It is clear that there are cost-effective savings available from replacing rather than rewinding electric motors. However there is not yet a firm proposal about how the Commission can ensure that those savings are achieved. The methods outlined in section 4.1.1 rely on information and persuasion. They are also low cost methods, and we have no objection to them. One risk that may arise in respect of education measures is of a time lag between education and the need for its application (ie failure date). An alternative (or complementary) approach that could be considered would directly subsidise motor upgrades. For example, to the extent that the tax system leads firms to rewind rather than replace motors, direct payments would help to counteract those incentives.

6. Conclusion

This report has considered the case for intervention by the Electricity Commission to promote better electricity efficiency in the area of compressed air systems and electric motors. The analysis drew on earlier work completed for the Commission, and on a range of other sources of information.

We found that there are significant electricity efficiency savings available, and that these seem likely to be obtainable in a cost-effective manner. That is, the benefits of the savings outweigh the costs of securing them.

There is a more reliable plan for obtaining efficiency gains in compressed air systems than in electric motors. For CAS, the proposed initiative is a Commission-funded audit programme for all except small and very small systems. This process has the advantage that savings can probably be achieved at whatever time the auditors do their work. By contrast, the main electric motor savings are only likely to be secured at the time a motor fails, which varies across firms. As a result, interventions need to focus on preparing firms to respond appropriately at that time.

Offsetting these certainty differences, the cost of the motors intervention appears considerably lower than for compressed air. For motors, an information campaign is required. It can operate through existing channels and draw on a range of partners, such as the motor supply and repair industry, and trade and business associations. Once the merits of upgrading motors are more widely understood, the process should be self sustaining. Additionally, the target is a one-time step change in the efficiency of the stock of motors, so the imperative for change will diminish as new motors are installed. For compressed air, the intervention is reasonably costly for the Commission, in the order of $1.2m plus internal costs of developing training materials and an audit monitoring programme.

Appendix A: Replacing vs Rewinding Motors

Both replacement and rewinding incur a one-off cost, from which a per-annum cost can be derived using an annuity formula. However, this simple calculation does not consider the tax benefits that each generates; benefits which are relevant to our analysis.

Rewinding is considered a current expense, and as such can be deducted against income and reduces the tax liability in the current year. With a company tax rate of 33%, this benefit is worth 33% of the rewinding cost. Replacement on the other hand, is considered capital expenditure and is depreciated over its useful life. This depreciation is an expense which reduces tax liability in each year of the motor's life. The benefit each year is 33% of the depreciation (which may vary across years).

The extra cost of replacement over rewinding per year is the difference between the after-tax annual cost of replacement and the after-tax annual cost of rewinding. The formulas for these two figures are outlined below.

Annual cost of replacement

The total cost of replacement is the one-off capital cost less the stream of tax benefits (in the form of reductions in tax liability through depreciation). The stream of benefits is discounted in the usual fashion. This total cost can be made to equal a stream of equal annual payments over the useful life of the motor, which are also discounted.

So:

$$\sum_{t=1}^{n} \frac{p}{(1+r)^t} = A - \sum_{t=1}^{n} \frac{c_t}{(1+r)^t}$$

where p is the annual cost, c_t the tax benefit in year *t*, A the one-off capital cost, r the discount rate, and n the useful life. Note that the tax benefits vary between years, while the annual cost does not.

Now the stream of tax benefits flow from the annual depreciation. We have assumed that annual depreciation is 20% of the book value. So the tax benefit is 33% of 20% of the book value.

So:

$$c_t = (0.33)(0.2)0.8^{t-1} A$$

We then solve this formula for p to derive the annual cost of replacement, as follows.

$$\sum_{t=1}^{n} \frac{p}{(1+r)^t} = A - \sum_{t=1}^{n} \frac{(0.33)(0.2)0.8^{t-1} A}{(1+r)^t}$$

$$= A - 0.066A\sum_{t=1}^{n}\frac{0.8^{t-1}}{(1+r)^t}$$

$$= A - 0.066A\left[\frac{\left(\frac{1}{1+r}\right)\left(1-\left(\frac{0.8}{1+r}\right)^n\right)}{1-\frac{0.8}{1+r}}\right]$$

$$= A - 0.066A\left(\frac{1-\left(\frac{0.8}{1+r}\right)^{12}}{0.2+r}\right)$$

Now using the standard annuity formula, we can re-write the left-hand side of this equation.

$$\sum_{t=1}^{n}\frac{p}{(1+r)^t} = p\left(\frac{1-\frac{1}{(1+r)^n}}{r}\right)$$

So now:

$$p\left(\frac{1-\frac{1}{(1+r)^n}}{r}\right) = A\left[1-0.066\left(\frac{1-\left(\frac{0.8}{1+r}\right)^n}{0.2+r}\right)\right]$$

Therefore:

$$\boxed{p = \frac{rA}{1-\frac{1}{(1+r)^n}}\left[1-0.066\left(\frac{1-\left(\frac{0.8}{1+r}\right)^n}{0.2+r}\right)\right]}$$

Annual cost of rewinding

The total cost of rewinding is the cost to get the motor rewound less the tax benefit accrued that year (generated by treating the rewinding cost as an expense). This total cost can be made to equal a stream of (discounted) equal annual payments over the useful life of the motor.

So:

$$\sum_{t=1}^{n} \frac{q}{(1+r)^t} = B - 0.33B$$

where q is the annual cost, B the one-off cost of rewinding, and 0.33B the tax benefit accrued in year 1.

Using the standard annuity formula, we can re-write the left-hand side of this equation.

$$\sum_{t=1}^{n} \frac{q}{(1+r)^t} = q\left(\frac{1-\frac{1}{(1+r)^n}}{r}\right)$$

So now:

$$q\left(\frac{1-\frac{1}{(1+r)^n}}{r}\right) = B(1-0.33)$$

Therefore:

$$\boxed{q = \frac{rB(1-0.33)}{1-\frac{1}{(1+r)^n}}}$$

Appendix B: Investment in Savings

When a policy initiative reduces the demand for electricity, resources are saved within the supply side of the electricity industry. The demand side initiative can be seen as a replacement for additional supply. The impact on total (social) costs then depends on which of the two methods for matching supply and demand uses the least valuable set of resources.

Individuals and firms have their own private incentives to save electricity when they can do so more cheaply than the retail price per unit of electricity. Retail prices, however, reflect more than just the resource cost of the electricity consumed. They must also recover the largely fixed costs of transmission and distribution, and the cost of retail service, both of which include any risk-related costs. Depending on the particular circumstances of the end-user, risk-related costs might include a premium over wet-year spot market prices to cover risks associated with providing electricity at an agreed fixed price.

For the Electricity Commission, a similar trade-off applies. However, since the Commission is acting as an agent for society as a whole, additional steps are required. Most obviously, the Commission should not intervene in ways that merely replicate private decision-making. Instead, it is obliged to ensure that it is addressing a genuine market failure, and generating benefits that exceed the costs it causes. Market failures are discussed section 2. The balance of this section analyses the costs saved by interventions that reduce demand.

What costs are saved?

Retail prices for electricity are made up of the following elements:

- Wholesale electricity costs which reflect short run marginal costs of supply, including the risk of hydro shortage and to trend towards long run marginal cost of new supply;
- Transmissions and distribution costs;
- Costs of sales.

Wholesale Energy

In the short run, the spot market clearing price indicates marginal cost of wholesale electricity. The market clears at a price sufficient to induce production from the most costly plant required to meet demand. So when a unit of demand is avoided, the spot market clearing price indicates the (short-run) value of that unit.

Spot prices are highly variable however, while the impact of interventions is ongoing. For practical purposes we are therefore obliged to use an estimate of average short-run supply costs to assess the value of electricity saved. This can be done in two ways. We can estimate the average fuel cost of marginal generation, and investigate spot prices directly.

Table 12 shows estimates of fuel costs by generation type, alongside an estimate of the percentage of time each is on the margin, and therefore the value of electricity savings. The weighted average short-run cost saving based on this analysis is 5.0c/kWh. This should be viewed as a lower bound on wholesale energy costs because it does not include compensation for any volume-related risks borne by generators.

Table 12 Short Run Marginal Costs of Generation

	Efficiency	Efficiency	Fuel cost	Fuel cost	O&M	Total Variable	Time on
Plant	%	GJ/MWh	$/GJ	c/kWh	c/kWh[1]	c/kWh	Margin[2]
Huntly (Coal)	35%	10.29	3.5	3.6	0.3	3.9	44%
CCGT	52%	6.92	6	4.2	0.3	4.5	35%
Oil	33%	10.91	18	19.6	0.3	19.9	8%
Hydro					0.6	0.6	13%
Weighted average						5	100%

[1] Source: East Harbour Management Services (2004) Fossil Fuel Electricity Generating Costs. Prepared for MED; [2] Concept Consulting Group (2004) Electricity Emission Factor Review. Prepared for NZ Climate Change Office.

This estimate can be compared with observed spot prices. Before that is done, three issues need to be considered. First, spot prices probably reflect the exercise of market power in some time periods; at those times, the spot price will overstate the resource cost of the last unit of energy supplied or saved. However unless market power is persistent rather than sporadic, the use of average spot prices will largely mitigate this issue. We consider that for present purposes it is reasonable to assume that any market power is sporadic.

Second, publicly available spot prices are simple (rather than demand weighted) averages over time. Since prices tend to be higher in peak demand periods, the publicly available data will therefore under-state the average spot prices paid and received.

Third, spot prices vary within and across years. In recent years, variation in average annual prices has mainly been linked to hydrological patterns: Figure 5 shows price peaks associated with the relatively dry conditions experienced in 2001 and 2003. However it also indicates an apparent secular shift upwards, particularly in 2005 and 2006 which were not regarded as dry years.

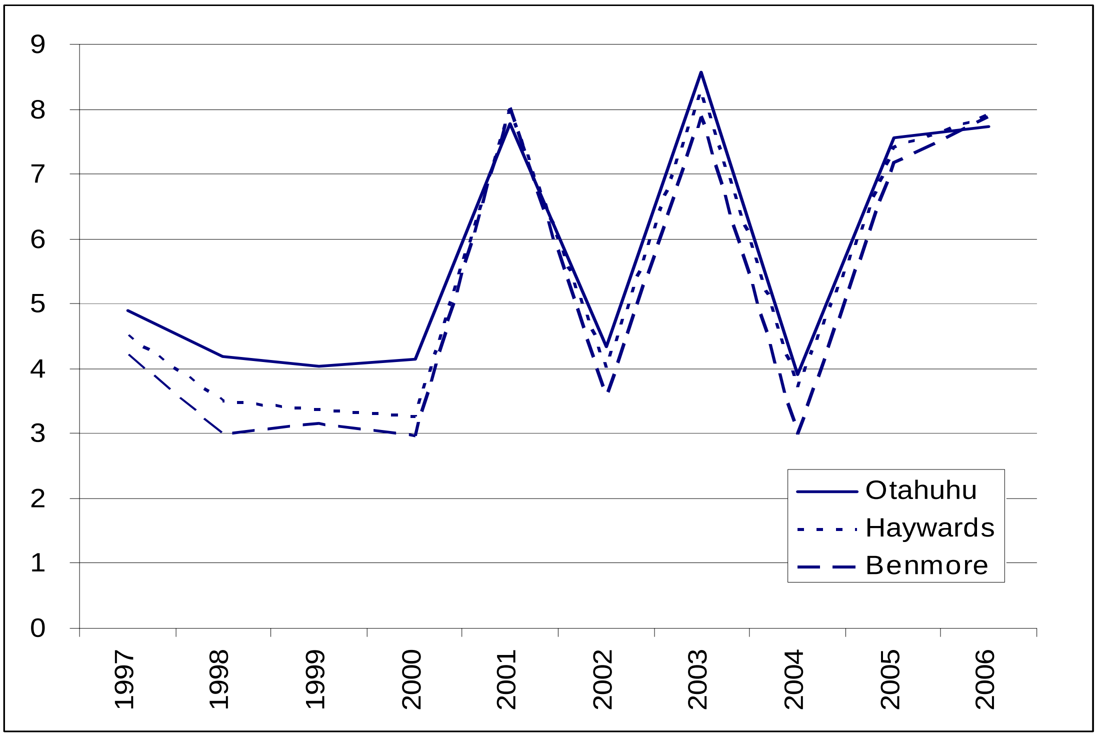

Figure 5 Wholesale spot prices (c/kWh) by location (source: ComitFree.co.nz)

More detailed information is available at the monthly frequency. Using the key Haywards node as the reference point, Figure 6 shows average monthly spot prices.

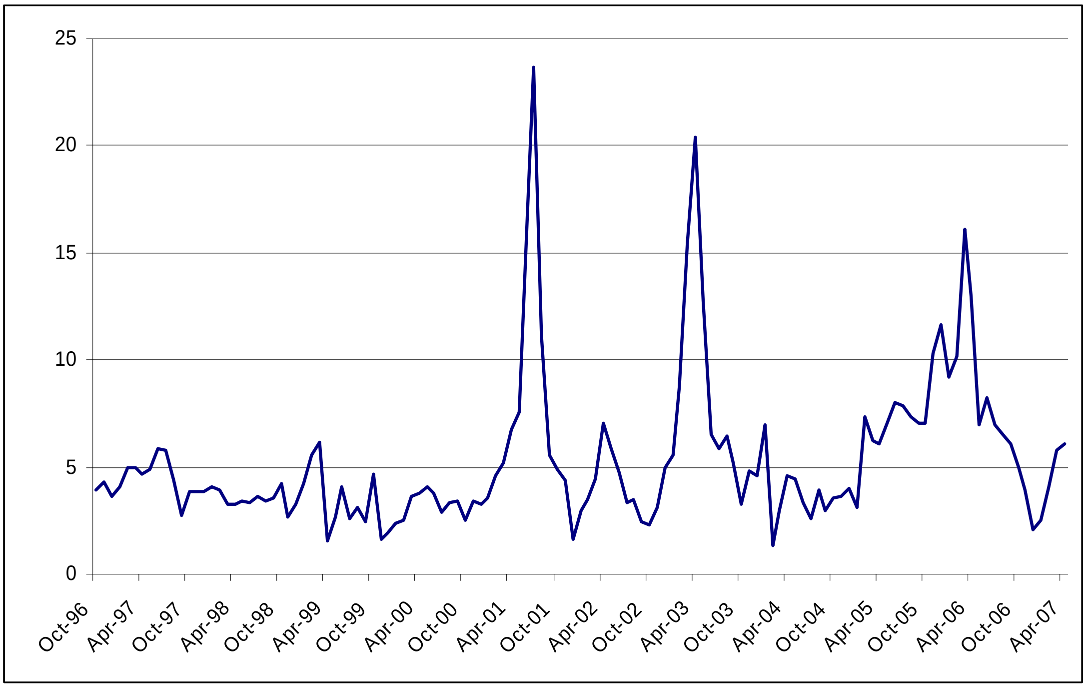

Figure 6 Monthly spot price at Haywards, October 1996-April 2007 (Source: ComitFree.co.nz)

The average of the Haywards monthly prices for the last year is 5.4 cents per kWh, and for the last two years it is 7.5 cents. On the basis of history, these figures provide a reasonable range of estimates of the value of saved energy in the short run. They are backward looking estimates, however.

Forward contract prices are not directly comparable with spot prices, because they contain what is effectively an insurance premium that users pay in return for stable prices. They do provide relevant and useful information however. Contract price data is demand weighted, but the market itself is relatively thin and the reported price indices are volatile.[18] For the first five months of 2007, two-year ahead contracts in the North Island have been trading in the 7.2 to 9c/kWh range.

Perhaps the greatest risk of upward shifts in spot prices is the possibility of a carbon trading regime, which is known to be under consideration. The impact of such an initiative on spot prices will depend heavily on the way credits are allocated, which is not currently known. However, since thermal plant is usually marginal in New Zealand's electricity market (Table 12), and will therefore be more exposed to the cost of carbon emissions, we believe some upward movement is likely.

In summary, there is no single number that reliably represents the short-run value of electricity savings. However on the basis of the information surveyed above, we recommend that the upper end of the historic range of spot prices should be used for evaluation purpose, ie 7.5 cents per kWh.

Why SRMC is a proxy for LRMC

Before leaving the question of the value of avoided generation, it may be helpful to explain why we recommend using estimates of SRMC as representing that value. The wholesale market in New Zealand is an energy-only market. Generators compete for dispatch at a half-hourly frequency and, at least in principle, recover all of their costs through energy sales.

Generation that is dispatched but not on the margin earns a surplus for its owner. It is paid a higher price than was offered into the market. These surpluses are used to recover fixed costs.

Some types of generation is much more likely to be on the margin than other types (Table 12). It has relatively fewer opportunities to earn a surplus by being paid more than its offer price. Offsetting this to some degree, it has some ability to set the price (ie some market power). That ability is constrained by the threat of new entry, with the result that spot market clearing prices will tend towards the cost of new supply, LRMC.

For this reason, the upper end of the range of observed spot prices can be viewed as an estimate of the LRMC of wholesale electricity.

[18] http://www.comitfree.co.nz/fta/ftaIndices.display_indices

Load profiles

The above analysis is based on average costs of wholesale electricity. In reality, costs vary at a half-hourly frequency. The value of an intervention therefore depends on the time profile of the reduced load. If the load targeted by an intervention is broadly similar to the system load profile, the average analysis above will be sufficiently accurate. Where it is known that the avoided load will be mostly peak load, slightly higher values could be used, and conversely where the avoidance is mostly off-peak.

Infrastructure and related costs

Savings resulting from interventions are likely to be ongoing rather than temporary. They will therefore avoid or at least defer the need for additional investment in transmission and distribution networks. This does not, of course, imply that no further investment is required or will occur. Nor does it deny the fact that investment in transmission and distribution networks tends to come in relatively large lumps. It merely underlines the fact that if a permanent load is removed from the system, future network expansions can be smaller, later in time, and/or less numerous.

There are several hurdles to estimation of the avoided infrastructure cost for the purpose at hand. In principle, one should analyse the impact of electricity saved on peak demand, which drives infrastructure investment. A key input into that analysis is the LRMC of transmission and distribution. However interventions with geographically dispersed effects will affect peak demand differently in different locations, and do so in ways that are difficult to estimate.

Additionally, the LRMC of transmission and distribution is not actually what is saved by electricity efficiency. Instead, efficiency measures merely defer the date at which the next increment is installed. The resulting saving is the opportunity cost of the associated capital over the time of deferral (eg 10% per annum). Implementing this approach would therefore require an understanding of how long particular investment projects could be deferred given the predicted demand reduction. The relatively complex process used in New Zealand for making grid investments decisions raises further barriers to the use of this approach.

We recommend a relatively simple alternative, based on an estimate of the infrastructure cost per unit of energy transported, rather a cost per unit of capacity. This relies on the fact that transmission and distribution networks are regulated, so that prices can be assumed to reflect infrastructure costs. We can therefore inspect the infrastructure component of retail prices to estimate the costs that might be avoided by interventions.

The Ministry of Economic Development report[19] the charges faced by residential consumers for the services of transmission and distribution networks. Figure 7 shows the most recently available data (August 2006) for this customer group. It is clear that

[19] http://www.med.govt.nz/templates/MultipageDocumentTOC____22959.aspx
Note that these data are based on an average residential usage of 8000kWh per annum.

lines charges vary considerably across the country. However for practical purposes average values can provide a reasonable estimate of these costs. The customer weighted average across the country is 7.6 cents per kWh including GST.

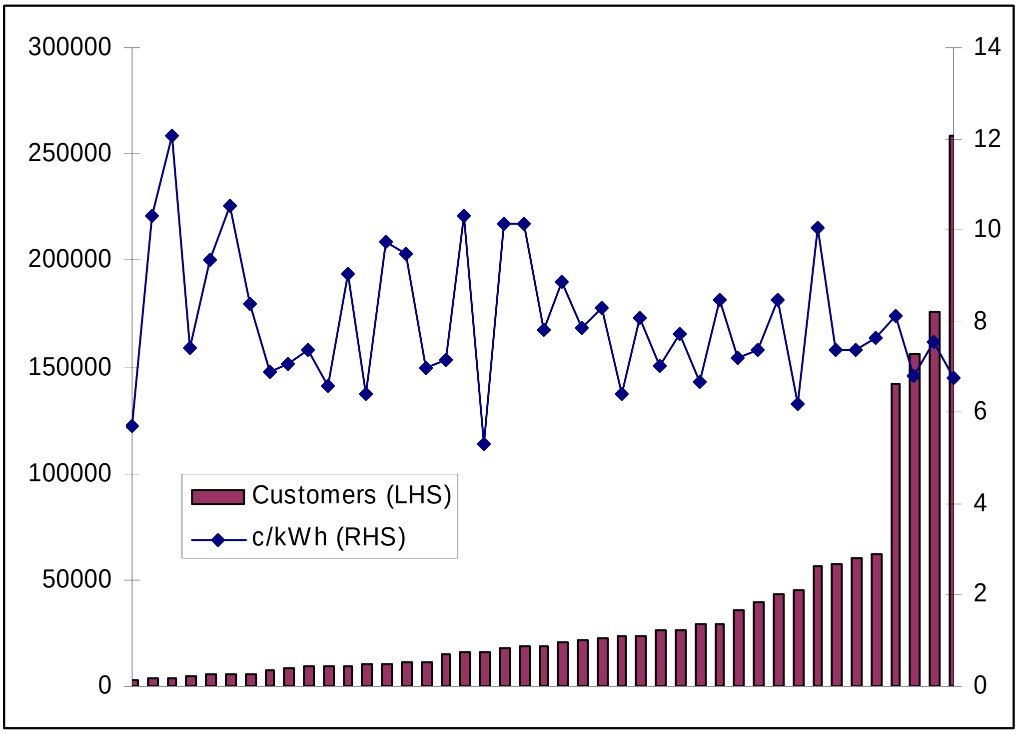

Figure 7 Transmission and distribution charges (C/kWh) and customer numbers (Source: MED)

We recommend that no allowance is made for retail cost savings. These costs are very difficult to estimate because retailers are integrated with generators and tend to report in aggregates. More importantly, retail costs (of which billing is the most important) depend mainly on the number of customers rather than the average amount of power used per customer. Interventions will not permit customers to disconnect their supply, so retail costs are unlikely to be saved.

Total cost savings

The above analysis is summarised in Table 13, which shows the total cost savings in cents per kWh over the short and long run.

Table 13 Total cost savings

	Short Run	Long Run
Energy	7.5	7.5
Infrastructure		7.6
Total	**7.5**	**15.1**

Projects that can reduce demand at a cost of less than 7.5c/kWh are clearly desirable even in the short run, and will deliver greater payoffs in future years as infrastructure costs are also avoided.