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ABSTRACT

A study of the energy savings potential in New Zealand schools demonstrates that considerable reductions in energy costs can be achieved through energy management. An initial examination of available 1985 light, heat, and water expenditures for 268 secondary schools (84 percent of the secondary schools in New Zealand) is followed by the selection of a number of schools for detailed investigation and for action. Three Wellington and four Christchurch schools were monitored with electronic dataloggers during winter 1986, both before and after action had been taken to improve energy management. In all cases remedial work was cost-effective, with pay-back times of not more than 2 years and in some cases of a few months. Savings in heating fuel costs through improved management ranged from 30 percent to 50 percent, far exceeding original estimates. Techniques used included walk-through energy audits, replacement of timeclock boiler controls with self-adaptive optimum start/stop controllers, runhour meters, and repair of faulty controls. Recommendations for further action are given, and a basic approach to an improved energy management program for the Department of Education is outlined. Dispersed throughout the text are 19 tables and 41 figures, and 19 references are included. The appendixes contain a sample printout illustrating the database structure and two summary reports regarding placing control systems in two schools. (MLF)

Victoria University of Wellington
School of Architecture

CLOSING THE LOOP - IMPROVING ENERGY MANAGEMENT IN SCHOOLS

ENERGY RESEARCH GROUP REPORT

Nigel Isaacs
Michael Donn

This paper is a draft final report describing a research programme funded by the Department of Education

Wellington, July 1987

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Abbreviations

Ag.	Agricultural
Coll.	College
C.R.O.	Central Regional Office, Department of Education
CR	Number of Classrooms
Elect	Electricity
E.O.	Executive Officer
H.S.	High School
LHW	Light, Heat and Water
M. & E.	Mechanical and Electrical Directorate, M.W.D.
M.W.D.	Ministry of Works and Development
N.Z.M.S.	New Zealand Meteorological Service
N.R.O.	Northern Regional Office, Department of Education
PERM	Permanent (classrooms)
P.M.G.	Property Management Group, M.W.D. (also known as Building Maintenance Group)
S.M.	Senior Master/Mistress
S.R.O.	Southern Regional Office, Department of Education
TEMP	Temporary (classrooms)
Temp	Temperature
W.E.B.	Wellington Education Board

Conversions

1 tonne coal	22.0 GJ (Average sub-bituminous)
1 KWh electricity	3.6 MJ
1 litre light fuel oil	38.6 MJ

SUMMARY OF RECOMMENDATIONS

Recommendations are listed in three groups:

1) Overall conclusions and recommendations for an Energy Management Programme;
2) Action for the Department of Education;
3) Further research or investigations required to implement an Energy Management Programme.

Section numbers where the recommendations are made are given in brackets.

Department of Education - Overall Recommendations for Action

THE WORK CARRIED OUT BY THIS PROJECT HAS DEMONSTRATED THAT REAL SAVINGS ARE POSSIBLE THROUGH IMPROVED ENERGY MANAGEMENT BASED ON A DATABASE SELECTION METHOD. A PROGRAMME OF ENERGY MANAGEMENT CAN NOW BE IMPLEMENTED WITHIN THE DEPARTMENT OF EDUCATION. (5.1)

Schools with excessive energy use should be identified using the approaches described in this report. Cost effective, corrective action can then be undertaken. (1.4)

The provision of incentives to schools to encourage their involvement in energy management be investigated. Sharing the savings achieved should be considered as incentives. Methods of measuring the savings are also required. (5.4)

The annual budget process recognise that there are long term costs associated with reduced spending on maintenance. The costs of not undertaking specific work are to be identified as well as the costs of doing the work. (2.2.3)

A computer based Schools Energy Database be created within the Department of Education. The type of computer used will depend on the proposed use of the database and its relationship to other building management information used by the Department. (2.3.1)

The Schools Energy Database be designed to permit examination of variations in energy use between schools. (2.3.4)

Modern control equipment requires ongoing support and maintenance. In the case of optimisers, this includes reprogramming each year before each heating season. All controls require regular checking and calibration. Funds must be available for this purpose. (4.2.6)

Caretakers must receive full training with any new equipment that is to be under their care. Ongoing programmes of support and training are also required. (4.2.6)

Department of Education - Recommendations for Action

Full Energy Audits be made of Teachers Colleges. (2.2.1)

The large discrepancy between maintenance expenditure per floor area between Secondary and Primary Schools be investigated, and maintenance funding increased for Secondary Schools. (2.2.4)

Secondary School annual energy accounts be delivered to the Department of Education by a fixed date each year. A suitable date might be three months after the financial year. (2.3.2)

Further investigation be undertaken into Integrated Schools' Light, Heat & Water expenditure. (2.3.6)

Credit notes to be archived with cheque or payment records. (3.1.1)

Energy data be recorded, and checked, at the same time as financial data in all computer based school accounts systems. (3.1.6)

An up-to-date register of building plans be maintained in each school. A condition of any maintenance, upgrading, construction or other significant work contract is for these plans to be upgraded. The register should be supervised by the Headmaster, Executive Officer or Caretaker. (3.2.1)

All school heating systems be provided with a brief (e.g. 1 page behind a clear, water proof, plastic cover) set of instructions mounted in the boiler house for ready use. Changes to the heating system operation must result in changes to the instructions. (3.2.1)

Management information on the existing Department of Education building stock must be in a more accessible form. (3.2.1)

An annually updated, standard format, register of key facts on each school be maintained by the service responsible for maintenance (i.e. Regional Office or Education Board). (3.2.1)

Energy bills subject to only a minimum charge for more than 12 months be investigated. Where possible, alternative arrangements for supply should be made or the supply disconnected. (3.2.2)

Improved boiler controls, such as optimisers, should be considered for installation in existing schools when replacement or upgrading is considered for the boiler control panels. (4.2.6)

When improved boiler controls are installed on an existing school heating system, full inspection and corrective action is to be undertaken prior to final commissioning. (4.2.6)

Self-adaptive optimisers should be installed in new schools. (4.2.6)

Research - Recommendations for Further Work

Analysis be undertaken to compare changes between years of Light, Heat & Water expenditure to determine patterns for subsequent use in the Energy Management Programme. (2.3.5)

Energy bills for schools monitored in 1986 be analysed for the 1987 heating season, and compared to earlier seasons to determine the actual benefits from changes instigated by this project. (4.1.6)

Further analysis be undertaken of the datalogger records of interior temperatures to determine the effect of continuous boiler operation on room temperatures. (4.1.6 a)

Rongotai College optimiser be monitored for a further season to determine the actual operation and whether OPTIMUM START or OPTIMUM STOP of the boilers is more important. (4.1.6)

The datalogger record for Rongotai College is a unique case of a school being heated for a four month continuous period. N.Z.M.S. climate data should be purchased for that period, and statistical comparisons made with all datalogger records to determine the importance of wind versus exterior temperature in the heating of schools. (4.1.7)

Further investigations should be undertaken into problems of different heating zones under one optimiser control. (4.2.6)

Further investigations be undertaken into opportunities for improved energy management in primary schools. (4.3.5)

A pilot project installing and monitoring 20 runhour meters be undertaken. (4.4.7)

1. INTRODUCTION

1.1 Purpose

This project commences from the conclusion of a previous study (Ref 1) carried out by the Energy Research Group (E.R.G.), viz.:

The reason for excessive energy use in schools is that energy is not properly managed.

This report shows that this lack of energy management results firstly from a lack of information for those responsible for maintenance, and secondly from an absence of any person who has responsibility for energy management.

1.2 Terms of Reference

A letter from the Department of Education dated 23 May 1985 (reference 41/17/141) established the terms of reference:

a) "Supply the Director (Research and Statistics) with 5 copies of a full and final report by 30 June 1987 on all aspects of the project which shall include:

1) Develop a school energy data base (S.E.D.A.B.).
2) Establish an administrative environment of a School Energy Data Base.
3) Generate,evaluate and refine an index or indexes of energy conservation potential.
4) Pilot the establishment of a school energy data base.
5) Use the S.E.D.A.B. and indexes of conservation potential to identify schools at both primary and secondary level, which have conservation potential.
6) Test conservation techniques in trial schools identified in (5) above.
7) Implement the use of all procedures in a set of schools.
8) Evaluate the success of the above procedures in practical application for both their ease of use and conservation efficacy."

b) In addition a summary of 1500 words and a nontechnical abstract of up to 200 words are also required.

This summary was based on the original proposal from E.R.G. dated June 1983 and modified by the revised statement of "Research and Development Tasks" dated July 1984, as given in the Appendix to the above contract letter.

1.2.1 Discussion

As outlined in the original contract proposal, this project was designed to work within the various educational institutions' existing management structures. Thus some parts of the tasks described above have not been implemented by the current project, but locations for future action have been identified.

Emphasis has been placed on the practical issues of improving energy management (items 5,6 & 7), with the theoretical and management implementation issues (items 1,2 & 3) undergoing selective examination. An initial S.E.D.A.B. (item 4) has been developed and investigated. This approach has been taken to ensure that the current situation is adequately defined/understood, before any changes can be instigated. This is to optimise the reduced expenditure on this contract as compared with the budget for the tasks set out in the original proposal dated June 1983.

1.3 Potential Cost Savings

In the 1985/86 financial year Government expenditure on Vote Education totalled $NZ2,010 million. Of this, $NZ134 million was for the Department of Education's Operating Costs. The expenditure on energy and water of $18.5 million was 14% of the Operating Costs. The previous E.R.G. study (Ref 1) concluded that potential energy expenditure savings of at least 16% could be achieved; that is $3 million per year.

According to M.W.D. estimates (Pool, pers. comm. 1986) total central government expenditure on energy was at least $150 million in the 1985/86 financial year. Table 1 places the Department of Education's expenditure in perspective with respect to building energy costs for other government departments and organisations. Although the Department of Education's expenditure is not the largest, it is still sizeable.

Table 1 : ESTIMATED N.Z. GOVERNMENT EXPENDITURE ON ENERGY 1985

Department Organisation	Annual Cost ($ million)	% of Total
Hospitals	45-50	32
Office Accommodation	22-30	17
Trading Departments	22-30	17
Tertiary Education	15-20	12
Department of Education	**13-18**	**10**
Defence	12	8
Justice	3	2
Research Institutes	2-3	2

Source: M.W.D. Estimates

Department of Education actual expenditure on Light, Heat and Water totalled $18.5 million in 1985/86.

1.4 Objectives of the Project

Schools, no less than other building types, are complex entities. A continual programme of maintenance is required to ensure both the individual components as well as the overall building system continue to operate at peak efficiency.

There is a need for suitable mechanisms to be available to maximise the return from the use of the limited funds available for maintenance. The design, construction and commissioning of a school are important to ensure a long life is possible, but the regular day-to-day and annual maintenance establish whether the buildings will actually have a long life. Ultimately the goal of this project is to provide a set of management tools that can be used to monitor and supervise the performance, or "well-being", of New Zealand schools.

As is shown in this report, the current situation is more akin to "Accident and Emergency" than "Primary Health Care". Remedial action is required immediately to bring school heating systems to an appropriate level of operation, but at the same time an ongoing

maintenance programme instituted. The problem then becomes the best way for limited funds to be spent. This project has developed indexes for the identification of schools with major energy problems. Although in New Zealand such schools are few in number, the potential savings from them alone are very large.
Causes of excessive energy use in schools can now be identified and where shown to be economical, corrective action should then be undertaken.

Recommendation : **Schools with excessive energy use should be identified using the approaches described in this report.** Cost effective, **corrective action can then be undertaken.**

Management implies an information flow with feedback, and improved ways of providing such feedback have also been investigated.

1.5 What is a school?

> "SCHOOL (n.) Institution for educating children or giving instruction usually of more elementary or more technical kind than that given at universities" (Concise Oxford Dictionary 5th Edition 1968)

A "school" is identifiable within the community, but as a category of buildings they are impossible to define. Almost any type of building on an infinite range of sites is likely. A school is a collection of buildings related by function but not by time of construction, type of construction or heating system. The New Zealand pattern of school development does not permit the existence of schools that are "genetically pure" with respect to their buildings e.g. a school may have started its life as a S68 model, but over the years it will have been extended, altered, reduced etc.

New Zealand schools do have one common feature - the provision of (often large) areas of playing grounds. Site areas can be large, with buildings very spread out. This gives significant energy losses in the transmission of heated water from a central boiler house, and the caretaker a very large site to supervise and maintain. Typically schools have a large number of small buildings with numerous windows and doors opening directly to the outside. Although this permits pupils ready exit and provides natural light it also increase heat losses due excessive natural ventilation.

1.6 School Buildings

School buildings are expensive assets which provide a range of services including:

- the use of the enclosed, conditioned space;
- educational facilities;
- comfort for the users;
- provision of community services; etc.

Energy is used in schools primarily to provide a comfortable environment, including heat and light, for staff and pupils. Therefore the only measure of performance which has lasting value is that of comfort. The ultimate goal of this study is to determine the most cost effective way of providing suitably comfortable conditions.

Private sector building owners have found intensive building management (including energy management) affects more than short term cost control. In the longer term, better maintenance of the building asset provides not only a better return on the capital invested (see Section 2.2.2), but also better, more productive working conditions for those who use the building. The same benefits will apply in the Public Sector. If plant and equipment is well maintained, better control over major maintenance or capital expenditure can be also expected because catastrophic equipment failures will be less likely.

Financial savings can be made through improved energy management of both the building and the energy using services. An earlier E.R.G. study (Ref 2) examined possibilities for altering school building design. This current study concentrates on services that use energy i.e. light and heat.

1. Report Outline

This report is submitted in fulfilment of the research contract undertaken by the Energy Research Group for the Department of Education. It summarises earlier research carried out by the Energy Research Group; the activities carried out for this contract; the results; and makes recommendations for future action by the Department of Education.

Chapter 1 provides background on the project and issues effecting improved energy management in the Department of Education. Chapter 2 investigates the currently available management statistics, and makes recommendations for the collection of additional data and further investigations. Chapter 3 examines the schools accounts and develops a Schools Energy Database.

Chapter 4 reports on the results of investigations in Wellington and Christchurch schools during the winter of 1986.

Chapter 5 provides a summary of the report conclusions and recommendations. Chapter 6 lists further research work required in the development of a full energy management programme within the Department of Education.

1.8 Staff

Harry Bruhns established the present form of the project and has been a continuing fund of information, ideas and suggestions. He is responsible for the design and structure of the database.

Colleen Wade collected and prepared the data from January through to December 1986.

Anne Brailsford - preparation and calibration of dataloggers.

Ernst Keller - preparation of monitoring equipment.

Robert Amor - computer program development and processing.

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Head Office - E.O. Buildings - Bruce Sheerin, Tony Dawe
- Finance Division - John Wilkinson

Christchurch - E.O. Buildings - Alan Thompson
- Regional Property Supervisor - John Hamilton

Wellington - E.O. Buildings - Len Youlden, Claire Frisbie
- Regional Property Supervisor - Bart Jansen

Wellington Education Board - Eric Sue, Steve Harvey, Don Fleming

Staff and pupils at the following schools -

Christchurch Secondary Schools:

Cashmere High School - E.O. Sandy Dunn; Caretaker Murray Gibb
Hillmorton High School - E.O. Bev Buxton; Caretaker Phil Woodhouse
Linwood High School - E.O. Merlyn Preece; Caretaker Murray Henry
Papanui High School - Head: Mr. Hay; Caretaker Ron Manning
Min/Max Temperatures Mr. Hall

Wellington Secondary Schools:

Rongotai College - Head: Mr. Powell; Caretaker Mike Hearn
Wellington College - E.O.: Colin Hall; Caretaker George Fowler
Wellington Girls - E.O.:Raewyn Coombes; Caretaker Harry Radcliffe

Wellington Primary Schools:

Oxford Crescent Primary - Head: Mrs. Ray; Caretaker Andy
Fraser Crescent Primary - Head: Mr. Healy:Caretaker Arthur Drabble
Khandallah Primary School - Caretaker Colin Biddle
Tawa Primary School & Evans Bay Intermediate School.

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1.10 Disclaimer

It is stressed that no conclusions should drawn from the situations described in this report with respect to specific Regional Offices, Education Boards, or even individual schools.

We expect there to be many more similar examples throughout the education system, but only a small number of schools were studied in detail, and comments can only be made on those cases.

2. MANAGEMENT STATISTICS

The study programme investigated two main areas, which in turn can be further subdivided:

Management Statistics

1) Management Statistics - Head Office - financial and other management information that is already collected by the Department of Education but not commonly used outside the collection centre.

2) Management Statistics - Regional - information that although collected currently by Head Office is applicable at the regional or district level for implementing, monitoring or running an energy management programme.

Individual School Data

3) Energy Use Information - At present energy accounts are handled along with any other school accounts and only total expenditure is available. Energy use data was extracted from the accounts by checking each account - many thousands in total. Physical inspections were made of a number of schools to determine what information was available on the design, construction and state of the heating system.

4) Investigations - based on analysis of the above data, a number of schools in Wellington and Christchurch were selected for detailed investigation, corrective action and monitoring.

Management statistics (items 1 and 2) are considered in this chapter, while individual school data (item 3) is considered in Chapter 3. The Investigations (item 4) are described in Chapter 4.

The approaches taken in this study provide the basis for a long term energy management programme within the Department of Education. However considerable flexibility was available in this study, and additional effort will be required to satisfactorily implement a full energy management system to become part of a larger routine Department of Education management system.

2.1 Head Office Management Statistics

This section presents information on the current costs of Light, Heat & Water in New Zealand Schools. All the raw data was obtained from the Department of Education, but the greatest problem was found to be the the detection and identification of the data and its location within the Department. The (almost total) separation of "Light, Heat & Water" expenditure (direct reimbursement through Grants Division, Finance) and "Maintenance" expenditure (paid by each Regional Office within the limits of the annual grant) from the end user (the school) has meant that a major part of the project has been concerned with management issues rather than the implementation of technical solutions to existing school plant and equipment.

As is standard Department of Education accounting policy, Light, Heat & Water and maintenance expenditure on integrated schools is included under "State" schools. Thus, as private schools integrate, their funding changes from being accounted as "Private" into the correct "State" school type.

2.1.1 Light, Heat & Water by School type

Figure 1 shows the distribution of Department of Education expenditure on Light, Heat & Water, compared to the Number of Schools and the Number of Pupils. It can be seen that expenditure on Light, Heat & Water appears to be more related to the number of pupils rather than the number of schools. There are considerably more Primary Schools than Secondary Schools, but each group spends, in total, about the same on Light, Heat & Water. If only equal percentage savings were likely to be achieved from improved energy management in all types of schools, then the greatest dollar savings per school would be achieved in the larger Secondary Schools. As the energy consuming systems are more complex in Secondary Schools, it is likely that the percentage savings will be greater.

Figure 2 illustrates the Light, Heat & Water expenditure per pupil based on the data provided in Figure 1. There is considerable variation between the school types, with State Primary Schools spending 42% less per pupil on Light, Heat & Water than State Secondary Schools.

This project has not been able to investigate Private Schools, Teachers Colleges or Technical Institutes but it is clear that the very large energy use per pupil at Teachers Colleges is worthy of more detailed study. Given the small number of Teachers Colleges, the indications are that full Energy Audits of each should be undertaken. While the total savings from each College may be relatively large, the national savings will be small, as all the Teachers Colleges in total consume less than 5% of the Departmental Light, Heat & Water budget.

Recommendation: Full Energy Audits be made of Teachers Colleges.

The raw data was obtained from the Departmental Annual Report (school and pupil numbers) and from the Notes to the Estimates prepared by the Department of Education, Finance Division.

2.1.2 Maintenance and Light, Heat & Water

In the 1985/86 financial year, Departmental expenditure on Maintenance totalled $32.2 million, compared with Light, Heat & Water expenditure of $18.5 million. Figure 3 compares total expenditure on maintenance (for all school types) by region. Figure 4 compares the floor areas (State Primary and State Secondary only) by region. Teachers Colleges and Technical Institutes represent only 7% of Maintenance expenditure and their omission from the data in Figure 4 should not detract from this comparison. It can be seen that maintenance expenditure region by region relates closely to the floor area of the buildings under care region by region. Thus the distribution of maintenance funds is well related to the regional floor areas.

Over the past years there has been a steady increase in expenditure on both Light, Heat & Water and Maintenance. Figures 5 and 6 show for State Primary and State Secondary schools respectively, that although actual expenditure has risen (thin lines), the same is not true in constant dollars (thick lines). Both Maintenance and Light, Heat & Water expenditures have been converted to constant (1982) dollars using a financial year based Consumers Price Index, and the Light, Heat & Water expenditure is in addition adjusted for the severity of the winter. The adjustment is calculated by relating the

COMPARISONS AMONGST SCHOOL TYPES

Department of Education Data

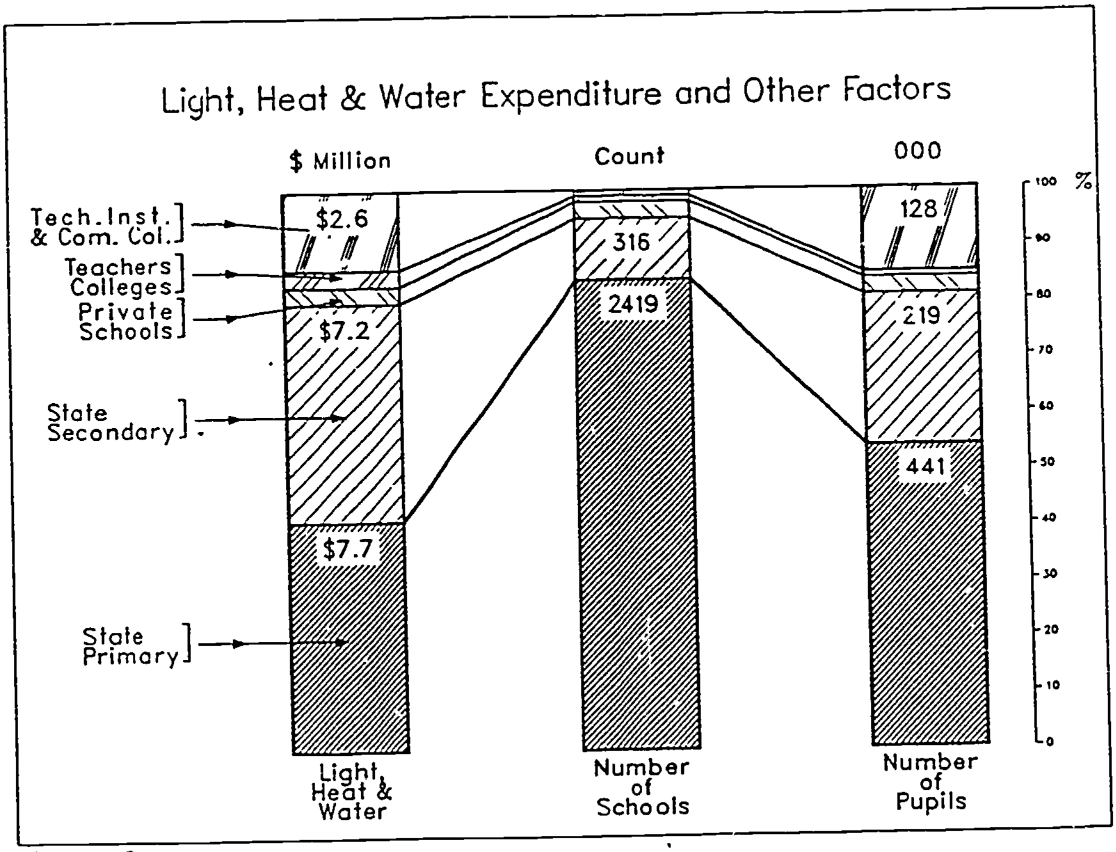

Figure 1

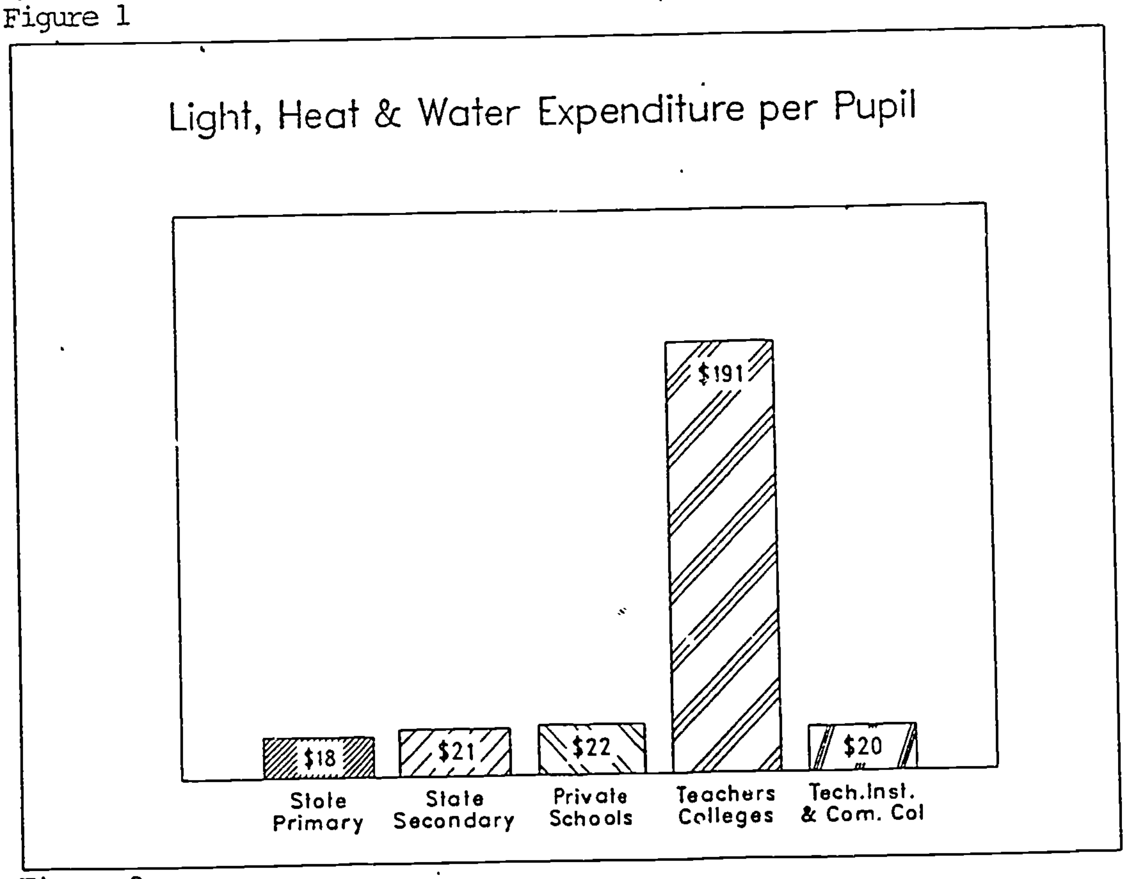

Figure 2

MAINTENANCE AND ENERGY EXPENDITURE

Department of Education Data

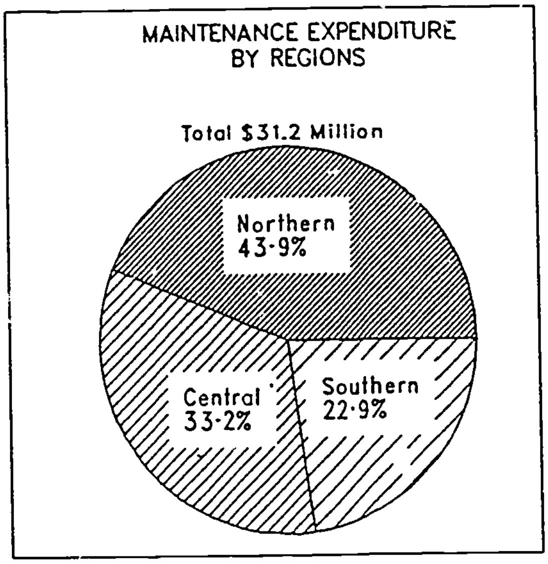

Figure 3

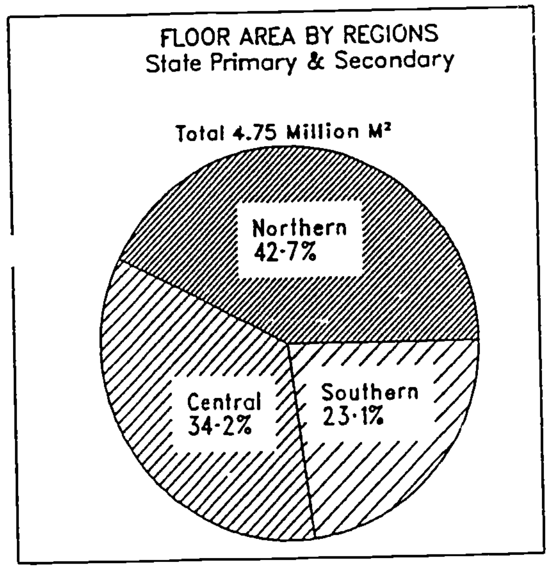

Figure 4

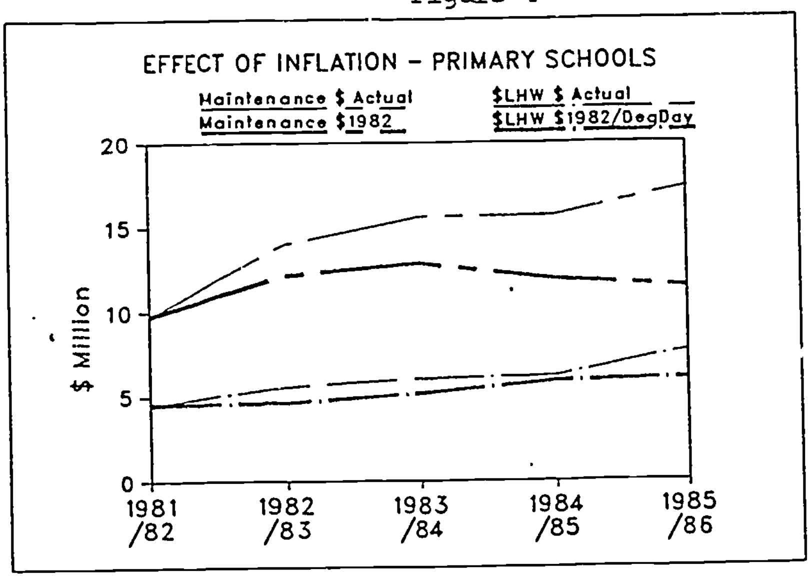

Figure 5

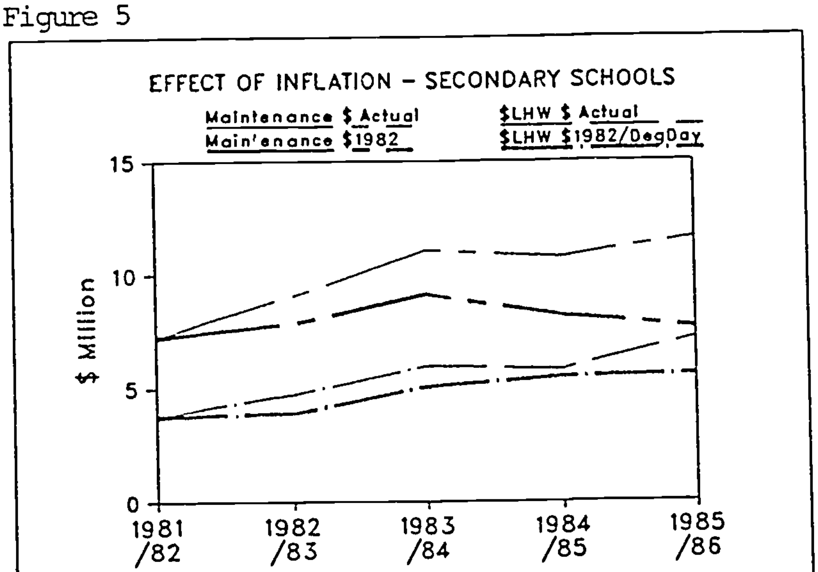

Figure 6

number of degree days in the year to the degree days in 1982, and then multiplying the expenditure by this ratio. Thus a colder year, with more degree days, will result in a reduction and vice versa. Maintenance expenditure is not divided into "buildings" and "plant" and hence the accounts quoted here may not relate directly to energy consuming services.

No simple relationship can be determined between the total Departmental expenditure on Light, Heat & Water and Maintenance, but it will be shown that in the secondary schools inspected by this project that the reduced maintenance of heating and distribution equipment has resulted in wasteful energy use (see Chapter 4).

Table 2 shows Primary School maintenance allocations for the period 1981/82 to 1986/87. Primary School maintenance allocations are based on floor areas, with an additional allowance ror a swimming pool. Although the basic allocation has increased actual dollars the same is not true when the same data is considered as constant, deflated, terms. In constant dollars there was an increase in Maintenance allocation from 1982/83 through 1984/85, but this has now become a decline.

Secondary School maintenance, although handled in the Regional Offices on a floor area basis, is not treated as such in the annual budget cycle. It is to be expected, assuming that the floor area of secondary schools has not altered significantly over the past six years, that a similar pattern to that shown in Table 2 for Primary Schools would prevail.

Table 2 : MAINTENANCE ALLOCATIONS FOR PRIMARY SCHOOLS

Allocation per m^2	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87
Actual $	$4.78	$5.49	$6.69	$7.29	$8.06	$9.11
% Change		15%	22%	9%	11%	13%
Deflated $ (1982)	$4.78	$4.76	$5.52	$5.53	$5.31	-
% Change		0%	16%	0%	-4%	

Source: Notes to the Estimates, Department of Education

It is well documented (e.g. Ref 2) that, as buildings increase in age, maintenance costs can also be expected to increase if the same standard of building is to be maintained.

Raw data was obtained from the Notes to The Estimates prepared by the Department of Education, Finance Division. Floor areas were obtained from the Executive Officer - Buildings in each of the regions.

2.1.3 Factors Affecting Light, Heat & Water

Figure 7 shows that the Light, Heat & Water expenditure per pupil in Secondary Schools ($32.81) is 53% higher than in Primary Schools ($17.44). Figures 8 through 12 provide other comparisons for examination of differences between Primary and Secondary Schools.

MAINTENANCE AND ENERGY EXPENDITURE 1985/86

Department of Education Data

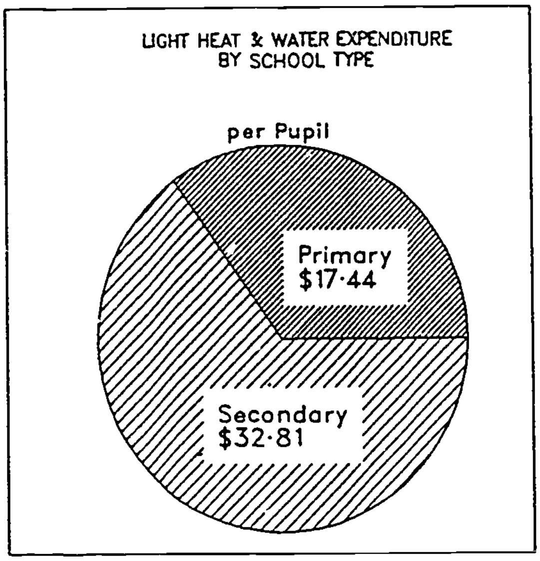

Figure 7

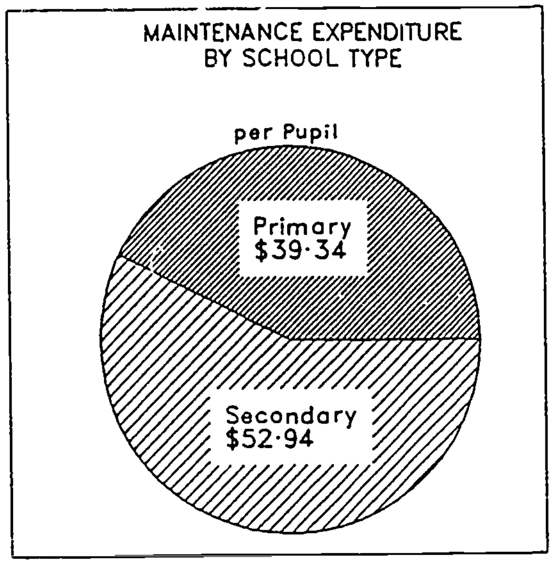

Figure 8

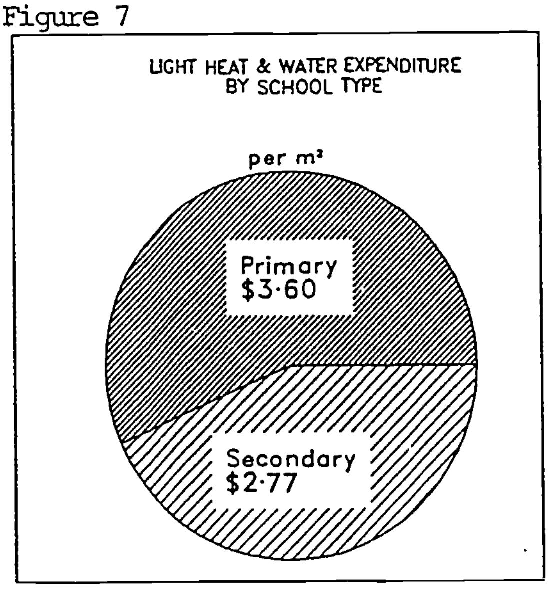

Figure 9

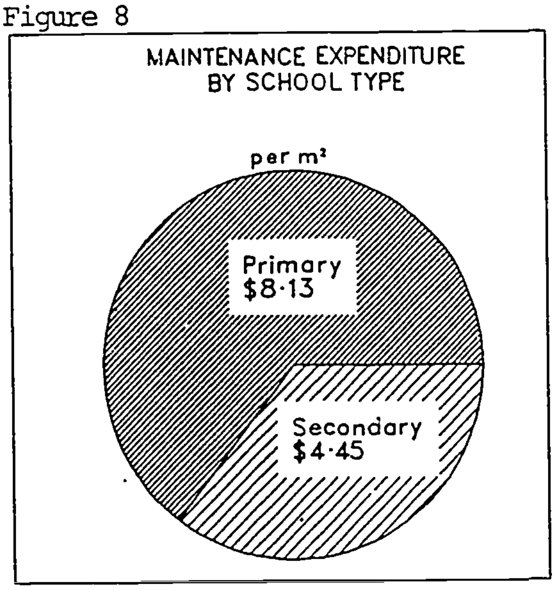

Figure 10

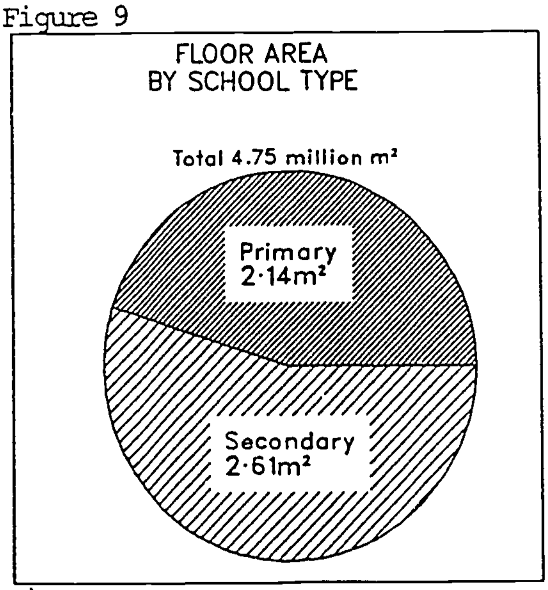

Figure 11

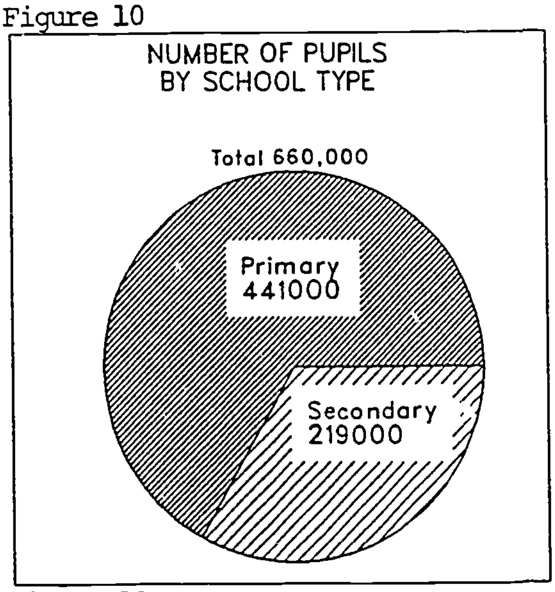

Figure 12

Figures 7 and 8 show that Primary Schools spend only 74% of the maintenance per pupil expenditure in Secondary Schools, while their Light, Heat & Water per pupil expenditure is 53% of Secondary Schools.

Figures 9 and 10 show that Primary Schools spend 83% more on maintenance expenditure per square metre than in Secondary Schools, and 30% more on Light, Heat & Water than in Secondary Schools.

Figure 11 shows that Primary Schools have 18% less floor area than Secondary Schools.

Figure 12 shows that Primary Schools have twice the number of pupils of Secondary Schools.

In summary, although Secondary Schools have half the number of pupils of Primary Schools, they have one fifth more total floor area but spend only half as much on maintenance per square metre of floor area.

Individual secondary schools are larger (in both pupil numbers and floor areas) than primary schools. Their operation is more complex, often with large central boiler systems feeding networks of pipes to deliver heat to widespread blocks. Secondary schools have more complex use patterns, including specialist rooms such as A.V. rooms and manual training workshops. Compared with primary schools. more money is spent on maintenance per pupil (Figure 9) but less is spent on maintenance per unit area (Figure 10).

Our previous study (Ref 1) found that the energy used by a school was related to the size of the school and the climate. In all cases, the area of the school (measured by square metres or numbers of classrooms) gave a stronger correlation to energy use than the number of pupils. This is possibly due to the fact that while roll numbers may change year by year depending on a range of variables, the school buildings remain in place.

These are not new facts, and in our discussions with staff of the Department of Education it has been clear that they are already well known within the Department. The issue is thus to ensure that those responsible for the funding of maintenance are aware of them in the process of allocating funds. The costs of doing no maintenance appear to be high.

Recommendation : **The annual budget process recognise that there are long term costs associated with reduced spending on maintenance. The costs of not undertaking specific work are to be identified as well as the costs of the work.**

2.1.4 Value of Schools

Schools have monetary value as well as having a value to the community as places for the provision of education. In the very worst case this is the cost of replacing the schools should some natural disaster make the building unusable. A failure to maintain the building fabric and facilities, although not as catastrophic as an earthquake, will in the long term have the same effect.

Table 3 shows that all schools under the direct control of the Department of Education have a current market value of at least

$1,306 million. Based on January 1987 insurance replacement costs for a "standard house" of $600 per square metre, the total replacement value is over $2,849 million.

Table 3 : VALUE OF DEPARTMENT OF EDUCATION SCHOOLS

	PRIMARY	SECONDARY	TOTAL
Improved Average Value per m^2 Department of Valuation 1983 data	$256	$294	---
Department of Education schools Total Value @ $600 per square metre ($Million)	$547.1	$767.6	$1,305.7
1985/86 Maintenance expenditure ($Million)	$17.4	$11.6	$31.9
Maintenance/School Value (c/$)	3.2c	1.5c	

Source: Department of Valuation and Department of Education

The proportion of Secondary Schools' Capital Value spent on maintenance is under half the proportion spent on Primary Schools. There are so many different ages and constructions of schools throughout New Zealand that no simple proportion can be set out as a guide, but this index again stresses that Secondary School maintenance is under funded compared with Primary Schools.

To increase secondary school maintenance expenditure to the same Maintenance per Capital Value ratio as primary schools would require an increase of $13 million to $25 million, while to increase it to the same Maintenance per Unit Area ratio would require an increase of $10 million to a total of $22 million.

Recommendation : The reasons for the large discrepancy between maintenance expenditure per floor area between Secondary and Primary Schools be investigated, and steps taken to increase funding for Secondary Schools.

2.2 Regional Management Statistics

Although Light, Heat & Water grants are paid directly from the Department of Education H.O., maintenance is handled on a regional basis. Property supervisors are located in the three Regional Offices, and in four other cities. Table 4 lists the offices and city districts:

Table 4 : DEPARTMENT OF EDUCATION CITY DISTRICTS

Regional Office	City
Northern	Auckland
	Hamilton
Central	Wellington
	Wanganui
	Napier
Southern	Christchurch
	Dunedin

This report will deal only with total Light, Heat & Water data for Secondary Schools because Primary School Light, Heat & Water total costs are not recorded in a central location for each school. Energy bill information for Wellington Education Board schools has been obtained and is discussed in Section 3.1. Analysis of Secondary Schools Light, Heat & Water has been undertaken by city districts, and is discussed in the following sections.

2.2.1 Data Sources

As a result of the earlier E.R.G. survey (Ref 1), Department of Education, Finance Division requested that Secondary Schools provide a breakdown of Light, Heat & Water costs by fuel types in their annual financial statements. The fuel cost breakdown is available for the 1984/85 and 1985/86 financial years. This information, along with other grant expenditures is loaded onto LOTUS123 spreadsheets by the Grants Section, and is used within that section for analysis, principally by school type, region and pupil numbers.

E.R.G. staff also loaded Light, Heat & Water expenditure from paper copies of school annual accounts into LOTUS123 spreadsheets. It took one person two half days to load this data for the available secondary schools. An existing spreadsheet base with school names, classroom numbers etc was used to minimise unnecessary data entry.

E.R.G. has added to spreadsheets supplied by the Grants Section the following additional information:

- city district;
- number of classrooms (permanent and temporary);
- floor area (if known); and
- a five letter school code.

This information thus forms a coherent database with previously collected data, and if maintained forms an invaluable future resource for the development of a full energy management programme within the Department of Education.

The analysis is limited by the number of schools that have supplied full financial accounts. The current Department of Education accounts system is not designed for the identification of expenditure on individual schools, and it is therefore necessary to obtain such information from the school. An energy management system for all schools would require such information to be available within the Department of Education.

Although an IBM PC compatible (640Kb of memory, no maths coprocessor) is capable of dealing with a LOTUS123 spreadsheet with one year's Light, Heat & Water data by fuel type, processing is slow. For example loading a large spreadsheet can take up to eight minutes. Two years of data results in unacceptably slow processing. Thus either a higher speed microcomputer is required, or preferably the use of a mainframe computer. A mainframe database with sufficient resources, including powerful statistical analysis software, will permit the creation of a longer term energy management database, permitting comparison across the years.

For the current project E.R.G. used the SAS (Statistical Analysis System - a trademark of the SAS Institute Inc.) software on the Victoria University IBM4341 mainframe computer, as well as LOTUS123 for specialised interactive analysis.

Recommendation : A computer based Schools Energy Database be created within the Department of Education. The type of computer used will depend on the proposed use of the database and its relationship to other building management information used by the Department.

2.2.2 Fuel Type By City

Figure 13 shows the reported use of each fuel type by city district. The Auckland city district is the largest, and reports the largest numbers of schools using each fuel type except for oil where Christchurch has the highest number of users.

A strong regional pattern of fuel types is not evident with every fuel type being used in every district, in similar proportions. For example approximately 60% of schools reported coal use in Auckland, Hamilton, Napier, Wellington and Dunedin. Only 37% used coal in Wanganui while 75% did in Dunedin. The use of gas in the South Island could be explained by the use of LPG for laboratories.

The number of schools in each fuel type given in Figure 13 do not add to the same as the "Total" count for that city. There are two reasons for this. Firstly it is to be expected that all schools use electricity, and more than one of the other heating fuels may be used. Secondly some school accounts listed only a Total Light, Heat & Water expenditure, and lacked an expenditure figure for the separate fuels.

Table 5 shows the total number of secondary schools by city district and the number of schools for which Light, Heat & Water expenditure is available. Auckland, Hamilton, Napier and Christchurch have over 90% of schools included in these analyses, Wanganui 86% and Wellington 76%. It is only in Dunedin that the proportion fall well below this, and therefore conclusions relating to Dunedin should be treated with caution.

Table 5 : NUMBER OF SCHOOLS WITH 1985
LIGHT, HEAT & WATER EXPENDITURE AVAILABLE

City	TOTAL NUMBER	Schools Count	%
Auckland	82	76	93%
Hamilton	48	47	98%
Wanganui	35	30	86%
Napier	24	23	96%
Wellington	46	35	76%
Christchurch	44	42	95%
Dunedin	37	14	38%
All New Zealand	316	267	84%

Source : Department of Education, 6 November 1986.

Recommendation : Secondary School annual energy accounts be delivered to the Department of Education by a fixed date each year. A suitable date might be three months after the financial year.

School heating systems are subject to regular review and consequential change, and it is possible that some of the schools reporting a fuel use in 1985 have since changed.

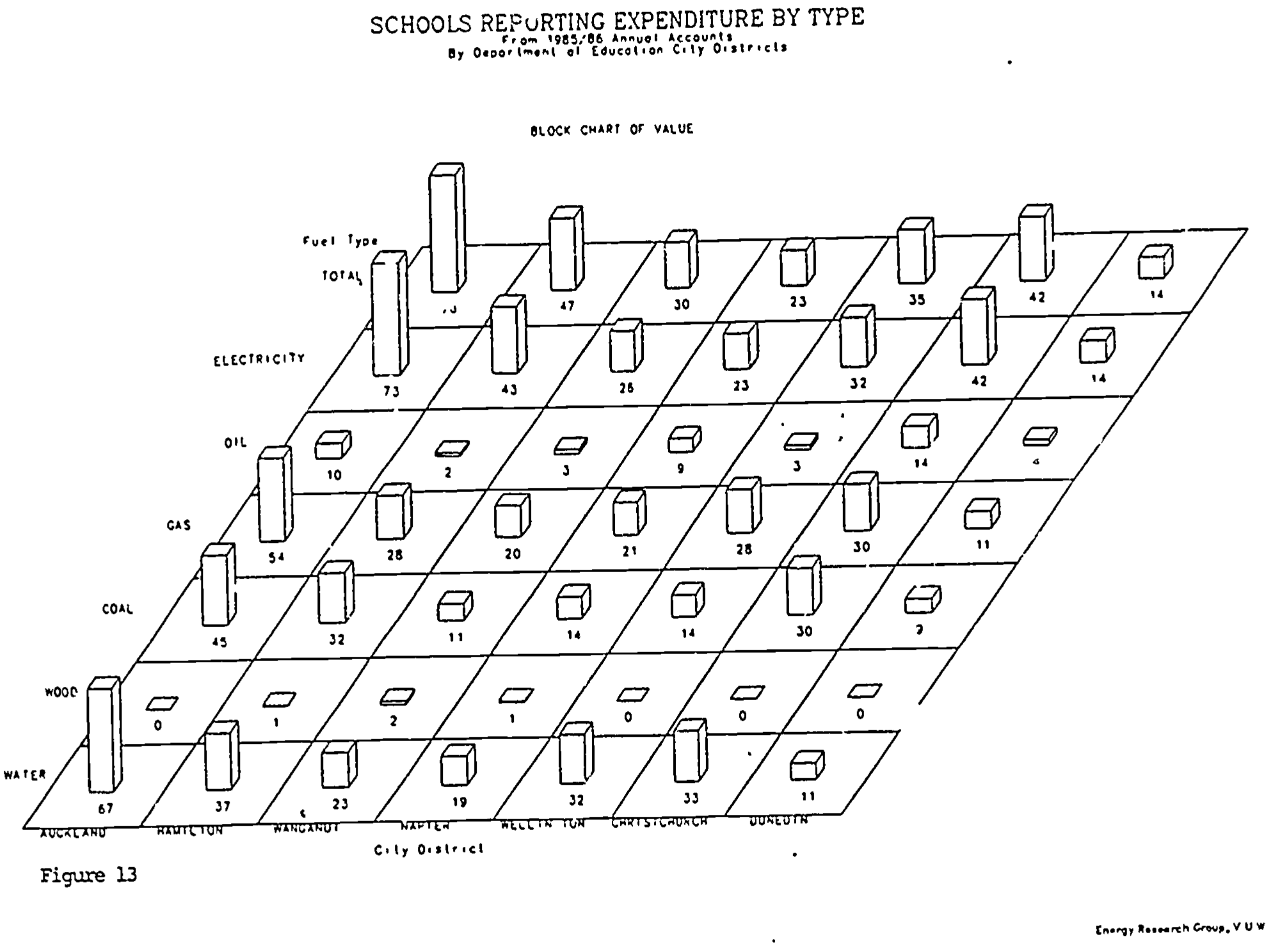
SCHOOLS REPORTING EXPENDITURE BY TYPE
From 1985/86 Annual Accounts
By Department of Education City Districts
BLOCK CHART OF VALUE
Fuel Type
TOTAL
ELECTRICITY
OIL
GAS
COAL
WOOD
WATER
47
30
23
35
42
14
73
43
26
23
32
42
14
10
2
3
9
3
14
54
28
20
21
28
30
11
45
32
11
14
14
30
0
1
2
1
0
0
0
67
37
23
19
32
33
11
AUCKLAND
HAMILTON
WANGANUI
NAPIER
WELLINGTON
CHRISTCHURCH
DUNEDIN
City District
Energy Research Group, V U W

Figure 13

2.2.3 Light, Heat & Water by Expenditure Size Groups

The schools for which expenditure was available were grouped by their Total expenditure on Light, Heat & Water and by city district. Figure 14 shows the amount spent in each expenditure group in each city, while Figure 15 shows the number and proportion of schools in each group.

Twenty-six schools spent over $40,000 in the 1985/86 financial year for a total expenditure of $1.287 million. The other 238 schools spent $3.972 million. Thus 10% of the schools, each spending over $40,000 in 1985/86 on Light, Heat & Water, spent 20% of the Total Light, Heat & Water. Table 6 lists the schools, ranking by city and Total Light, Heat & Water. Auckland has four schools in this group, Hamilton two, Wanganui one, Wellington nine, Christchurch five and Dunedin five. There is no obvious regional pattern with respect to the number of schools in each city.

Examination of Total Light, Heat & Water expenditure inevitably highlights larger schools. Figure 16 shows the number and proportion of schools grouped by Light, Heat & Water expenditure per classroom, a measure of energy use intensity rather than just size. Thirty-one schools (15%) had Light, Heat & Water expenditure per classroom of greater than $800 in 1985/86. Table 7 lists the schools, ranking by city and Light, Heat & Water per classroom. Auckland has one school in this group, Hamilton two, Wanganui two, Napier two, Wellington seven, Christchurch ten and Dunedin seven. Again there is no obvious regional pattern with respect to the number of schools in each city selected by expenditure per classroom on Light, Heat & Water. Total expenditure for these schools in the 1985/86 financial year was $1.189 million.

Schools in the top groupings for both Total Light, Heat & Water and Light, Heat & Water per classroom are marked by an asterisk ("*"). Thirteen schools spending over $40,000 on Light, Heat & Water (50% of 26 schools) are also in the top group spending over $800 on Light, Heat & Water per classroom (42% of 31 schools). These 13 schools had a total expenditure of $0.66 million.

High Total Light, Heat & Water expenditure implies that if percentage savings can be achieved through improved energy management, the returns will be large. High expenditure on Light, Heat & Water Per Classroom implies that for some reason it is more expensive to maintain the classrooms at the levels required. As this comparison assumes all schools to use energy only to provide similar comfort levels, differences could be due to inefficiency or a large energy using activity being carried on in one school compared to another. For example if one school has a pottery kiln, higher energy use would be apparent compared with another school lacking this facility.

Different energy forms have different costs, with electricity in general having the highest. Thus schools that are heated with electricity can be expected to cost more to run than schools heated with natural gas or coal. For this reason analysis based on Total Light, Heat & Water must be combined with analysis of the individual fuels. If a school has high Total Light, Heat & Water expenditure, plus a high figure for Light, Heat & Water Per Classroom and has a high individual expenditure on the individual fuel, then it is very

1985/86 LIGHT, HEAT & WATER EXPENDITURE

By Department of Education
City District

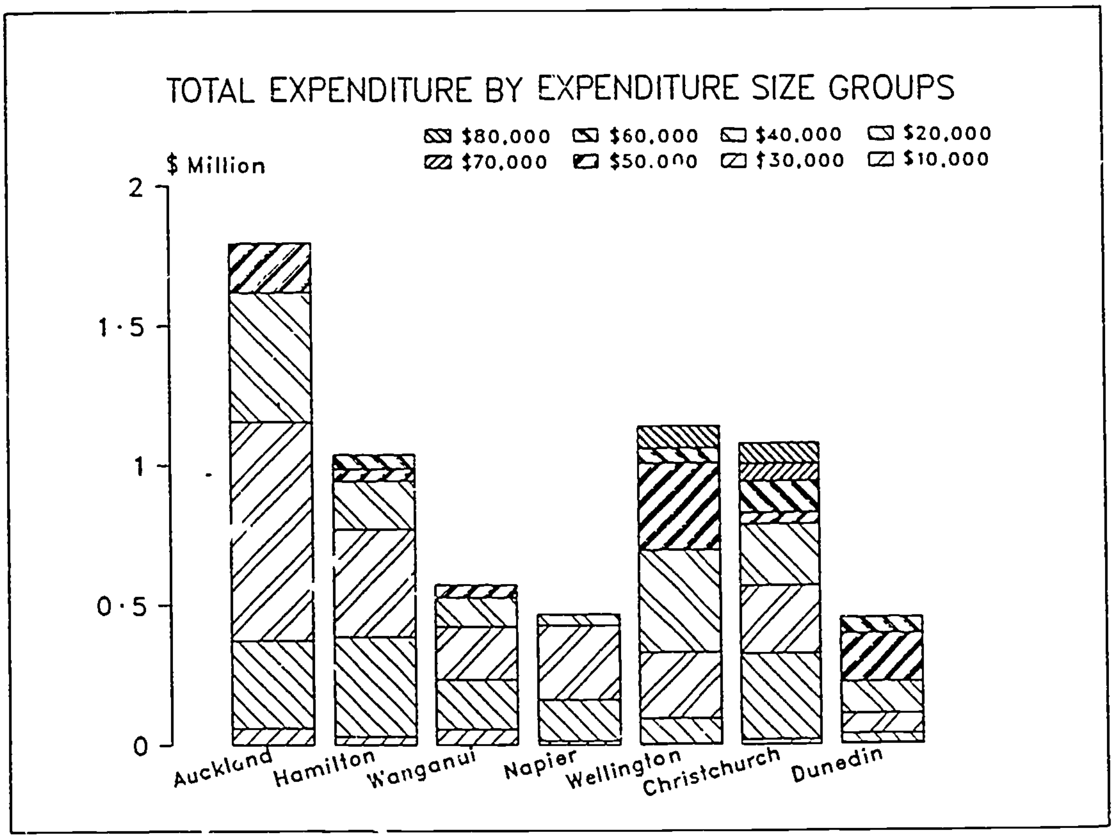

Figure 14

Notes:
Total expenditure in each of the expenditure size groups was calculated by:
1) Sorting all secondary schools for which 1985/86 Light, Heat & Water expenditure was available by city district;
2) Ranking the expenditure;
3) Determining the frequency distribution in expenditure group steps of $2500; and
4) Multiplying the count (number of schools) in each group by the maximum expenditure for that expenditure group.

Thus the tip of each expenditure size group represents the total amount all the schools in that group spent on Light, Heat & Water. The shading patterns used on Figure 14 and Figure 15 are identical, and thus the number of schools in each size group can easily be determined.

For example, in Auckland, 13 schools each spending between $30,000 and $40,000, spent in total $450,000. Overall, Auckland schools spent $1.75 million on Light, Heat & Water.

1985/86 LIGHT, HEAT & WATER EXPENDITURE

By Department of Education
City District

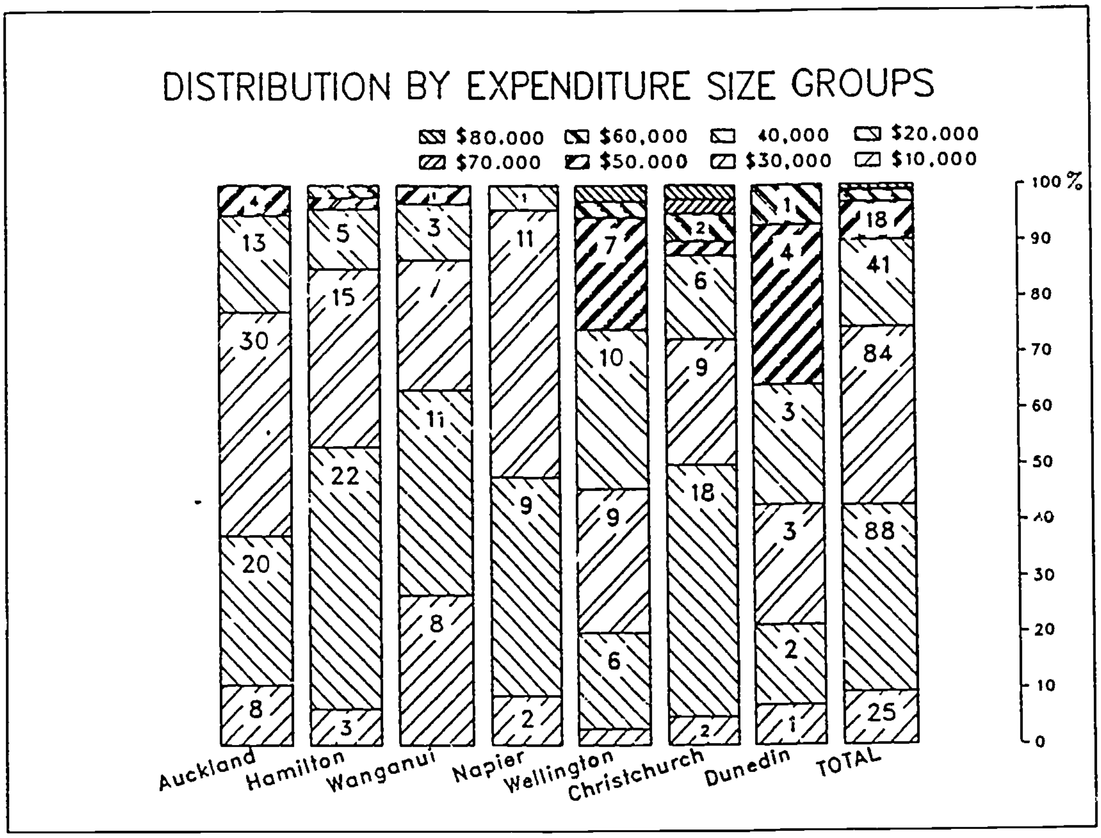

Figure 15

Notes:
Expenditure size groups were calculated by:
1) Sorting all secondary schools for which 1985/86 Light, Heat & Water expenditure was available by city district;
2) Ranking the expenditure;
3) Determining the frequency distribution in expenditure groups of $10,000; and
4) Calculating the percentage of the total number of schools in each city represented by the number of schools in that expenditure group.

Thus the tip of each expenditure size group gives the percentage of all schools in that city spending up to the top of that group on Light, Heat and Water. The shading patterns used on Figure 14 and Figure 15 are identical.

For example, in Auckland, the 13 schools each spending between $30,000 and $40,000, represented 17% of the total expenditure on Light, Heat & Water. It can thus be seen that only a few schools have high expenditure on Light, Heat & Water.

The distribution of expenditure size groups between cities is also interesting. It can be seen that the top two expenditure groups i.e. over $70,000 on Light, Heat & Water, were represented only in Wellington and Christchurch.

likely that improved energy management would achieve significant savings. Tables can be generated for each fuel type, and used for the detection (and selection for detailed investigation) of schools with high fuel use. Chapter 4 gives examples of such a process.

Table 6 : SCHOOLS WITH LIGHT, HEAT & WATER EXPENDITURE GREATER THAN $40,000 IN 1985/86

Schools ranked by Light, Heat & Water expenditure by City District

	1985 Classrooms		Total Expenditure					Per Classroom Expenditure				
Schools	PERM	TEMP	TOTAL	ELECT	GAS	OIL	COAL	TOTAL	ELECT	GAS	OIL	COAL
Auckland												
Auckland Grammar S.	54.0	10.0	45559	24602	4551			712	384	71		
Birkdale College	48.0	11.0	44958	29704	698		4298	762	503	12		73
Papakura H.S	54.0	12.0	42401	37805	504			642	573	3		
Henderson H.S.	54.3	9.0	40316	18911		12828		637	299		203	
Hamilton												
*Forest View H.S.	32.0	7.0	51591	29064	21331			1323	745	547		
Hamilton Boys H.S.	42.0	16.0	40383	20720	14015			696	357	242		
Wanganui												
Fielding Ag. H.S.	57.5	9.0	46788	19831	16847			704	298	253		
Wellington												
*Wellington College	47.0	9.0	78914	31067	3210	35104		1409	555	57	627	
Hutt Valley H.S.	59.0	11.0	50090	30599			14449	716	437			206
*Wellington H.S.	44.0	7.0	47429	36029	8443			930	706	166		
*Rongotai College	44.0	5.0	46527	23554	19478			950	481	398		
*Paranaraumu Coll.	42.0		43561					1037				
Tawa College	60.3	3.0	43165	18505	18277			682	293	289		
Upper Hutt College	54.5	12.0	41631	23962	572		11922	626	360	9		179
*Onslow College	45.0	4.0	41590	19970	15106			849	408	308		
*Taita College	41.0	5.0	40693					885				
Christchurch												
*Ashburton College	65.0	12.0	71963	57438	202	554	8905.	935	746	3	7	116
Burnside H.S	91.0	4.0	60460	23968	97	130	24799	636	252	1	1	261
*Hagley H.S.	38.0	11.0	56866	29149	337	26441		1161	595	7	540	
Rangiora H.S.	47.0	21.0	54023	42768			11255	794	629			166
*Mountainview H.S.	29.0	5.0	40875	29619	1185		7706	1202	871	35		227
Dunedin												
*Waitaki Boys H.S.	35.0	9.0	58774	36734	-24		18968	1336	835	-1		431
James Hargest H.S.	52.0	2.0	42592	21749	106	352	15497	789	403	2	7	287
*Southland G. H.S.	41.0	3.0	41403	21841	1102		16300	941	496	25		370
Twizel H.S.			41245	41245								
*Cargill H.S.	41.0	2.0	40479	23934	631	356	13584	941	557	15	8	316

Note:
* Schools listed for both Total and Per Classroom Light Heat & Water expenditure.

Data Sources:
Expenditure - Department of Education LOTUS123 spreadsheets supplied by Grants Section, Finance Division.
Classroom Numbers - Accommodation Schedules from Buildings Division.

1985/86 LIGHT, HEAT & WATER EXPENDITURE

By Department of Education
City District

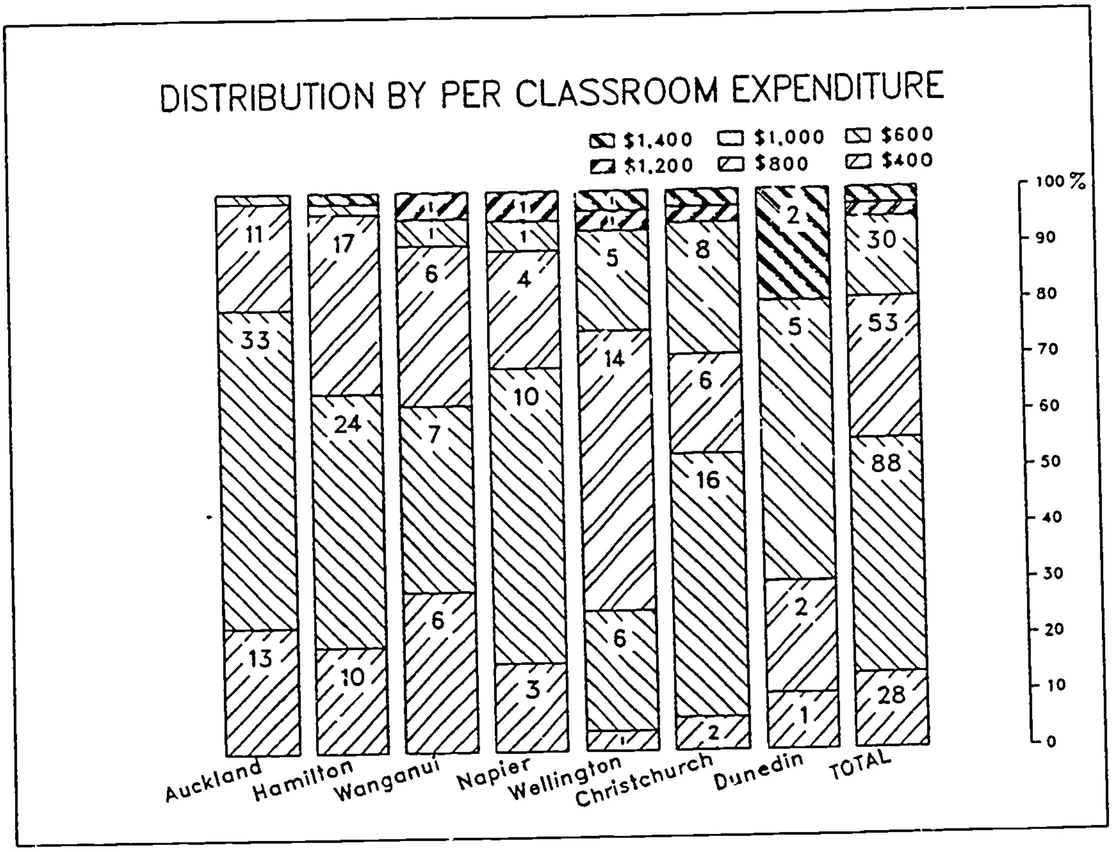

Figure 16

Notes:
Per Classroom expenditure size groups were calculated by:
1) Sorting all secondary schools for which 1985/86 Per Classroom Light, Heat & Water expenditure was available by city district;
2) Ranking the per classroom expenditure;
3) Determining the frequency distribution for expenditure groups of $200; and
4) Calculating the percentage of the total number of schools in each city represented by the number of schools in that group.

Thus the tip of each expenditure size group gives the proportion of schools in that city that had a per classroom expenditure on Light, Heat & Water less than the range indicated by the shading pattern.

For example, in Auckland, 11 schools each spending between $600 and $800 represented 18% of the Auckland schools for which Light, Heat & Water expenditure per classroom was available. Thus only a small number of schools in each city have a high per classroom Light, Heat & Water expenditure.

The distribution of per classroom expenditure size groups between cities is also interesting. It can be seen that the top two expenditure groups i.e. over $1,200 per classroom on Light, Heat & Water, are represented in all cities except Auckland, and are also only few in number.

Table 7 : SCHOOLS WITH LIGHT, HEAT & WATER PER CLASSROOM EXPENDITURE GREATER THAN $800 IN 1985/86

Ranking by Light, Heat & Water per classroom expenditure and by City District

Schools	1985 Classroom		Total Expenditure					Per Classroom Expenditure				
	PERM	TEMP	TOTAL	ELECT	GAS	OIL	COAL	TOTAL	ELECT	GAS	OIL	COAL
Auckland												
Nga Tapuwae College	44.0	1.0	38523	22868	1671		1958	856	508	37		44
Hamilton												
*Forest View H.S.	32.0	7.0	51591	29064	21331			1323	745	547		
Reporoa College	18.0	6.0	20473	13347	2201		4562	853	556	92		190
Wanganui												
Ruapehu College	24.0	4.0	30339	24903	90		5346	1084	889	3		191
Opunake H.S.	18.0	10.0	23609	21009	147	530	1728	843	750	5	19	62
Napier												
Te Aute College	12.0	5.0	17059	11534	164		5362	1003	678	10		315
Dannevirke H.S.	41.3	3.0	37603	29863	20	1326	4443	850	675		30	100
Wellington												
*Wellington College	47.0	9.0	78914	31067	3210	35104		1409	555	57	627	
*Paraparaumu Coll.	42.0		43561					1037				
*Rongotai College	44.0	5.0	46527	23554	19478			950	481	398		
*Wellington H.S.	44.0	7.0	47429	36029	8443			930	706	166		
*Taita College	41.0	5.0	40693					885				
Parkway College	35.0	4.0	34061	17285	1775		13777	873	443	46		353
*Onslow College	45.0	4.0	41590	19970	15106			849	408	308		
Christchurch												
*Mountainview H.S.	29.0	5.0	40875	29619	1185		7706	1202	871	35		227
*Hagley H.S.	38.0	11.0	56866	29149	337	26441		1161	595	7	540	
*Ashburton College	65.0	12.0	71963	57438	202	554	8905	935	746	3	7	116
Westland H.S.	28.0	3.0	28306	14939	137		8771	913	482	4		283
Kaiapoi H.S.	31.0	7.0	34195	20286	492		11528	900	534	13		303
Timaru Girls H.S.	30.0	12.0	37450	21961	441		14039	892	523	11		334
Sacred Heart G.Coll.	21.0		18629	12357		5788		887	588		276	
Waimate H.S.	31.0	3.0	29128	18483	.		10645	857	544			313
Timaru Boys H.S.	32.0	6.0	31816	20578	586	29	8815	837	542	15	1	232
Methven H.S.	16.0	2.0	14661	9227		345	4562	815	513		19	253
Dunedin												
*Waitaki Boys H.S.	35.0	9.0	58774	36734	-24		18968	1336	835	-1		431
Fiordland College	15.0	3.0	21733	14093	759		6882	1207	783	42		382
*Southland G. H.S.	41.0	3.0	41403	21841	1102		163[illegible]	941	496	25		370
*Cargill H.S.	41.0	2.0	40479	23934	631	356	13584	941	557	15	8	316
Kingswell H.S.	43.0		38735	16099	3454	344	14030	901	374	80	8	326
Southland Boys H.S.	40.0	3.0	37003	18018	1589	194	11178	861	419	37	5	260
Waitaki Girls H.S.	29.0	11.0	33213	20539	158		11072	830	513	4		277

Note:

* Schools listed for both Total and Per Classroom Light Heat & Water expenditure.

Data Sources:

Expenditure : LOTUS123 spreadsheets - Grants Section.

Classroom Numbers : Accommodation Schedules - Buildings Division.

2.2.4 Minimum, Mean and Maximum Light, Heat & Water Expenditure

Table 8 gives the minimum, mean and maximum expenditure for classroom numbers and each fuel by city district. Each fuel and classroom type has been evaluated separately, and thus no one school will have all values. This data is also given in Figure 17 through Figure 21 for total expenditure and Figure 22 through Figure 26 on a per classroom basis.

Table 8 : CITY MINIMUM, MEAN AND MAXIMUM EXPENDITURE BY FUEL TYPE

	1985 Classroom		Total Expenditure						Per Classroom Expenditure				
City	PERM	TEMP	TOTAL	ELECT	GAS	OIL	COAL	WOOD	TOTAL	ELECT	GAS	OIL	COAL
Auckland													
Minimum	16.0	1.0	2180	1803	13	0	0	0	223	116	1	3	25
Mean	42.6	8.8	22361	14809	1085	7844	3103	0	489	318	24	136	63
Maximum	66.0	20.0	45559	37805	12083	19246	5669	0	856	573	195	276	161
Hamilton													
Minimum	14.0	1.0	8802	2300	10	226	960	180	217	43	1	4	34
Mean	35.2	8.4	20644	14278	2366	1865	3811	180	507	357	65	58	94
Maximum	61.0	20.0	51591	29064	21331	3503	8818	180	1323	745	547	113	200
Wanganui													
Minimum	15.0	1.0	3659	2980	11	530	216	60	208	138	1	19	10
Mean	38.2	5.7	17817	11905	3837	6531	4389	60	549	358	95	182	140
Maximum	65.0	14.0	46788	24903	16847	13881	15055	60	1084	889	253	288	327
Napier													
Minimum	12.0	1.0	3229	2997	20	19	3436	0	333	243	1	6	69
Mean	38.2	4.4	20094	13080	548	5545	5494	0	555	371	15	146	135
Maximum	55.0	8.0	37603	29863	2290	11684	10853	0	1003	678	44	272	315
Wellington													
Minimum	19.0	1.0	4472	1922	17	673	2706	0	381	183	3	13	77
Mean	42.5	5.9	31130	17722	5101	14347	8904	0	709	396	116	266	183
Maximum	60.3	14.0	78914	36029	19478	35104	16946	0	1409	706	398	627	353
Christchurch													
Minimum	13.0	1.0	2039	1965	53	8	2490	0	322	141	1	1	63
Mean	36.9	6.8	24433	15152	429	3470	8617	0	653	401	11	101	201
Maximum	91.0	21.0	71963	57438	1543	26441	24799	0	1202	871	50	540	334
Dunedin													
Minimum	15.0	1.0	6450	5601	35	194	6882	0	280	244	2	5	260
Mean	33.0	4.8	31128	19845	815	311	13235	0	881	502	26	7	330
Maximum	52.0	11.0	58774	41245	3454	356	18968	0	1336	835	80	8	431

NOTE : Analysis uses only those schools for which data is available.
Minimums are from non-zero and not missing schools by fuel.

Figures 17 through 21 graph the minimum, mean and maximum Light, Heat & Water by city district for Total Light, Heat & Water and the individual fuels, viz. Electricity, Gas, Oil and Coal. The tip of each shaded portion represents the minimum, mean or maximum. There does not seem to be a pattern of energy expenditure being related to latitude with respect to total costs. It is interesting to note that it is Wellington that has the largest maximum total and oil expenditures. Christchurch has the largest maximum electricity expenditure.

Figures 22 through 26 present comparable data on a per classroom basis. There is a small, but noticeable trend that both mean Total Light, Heat & Water and mean Electricity expenditure increase with increasing latitude. Mean Coal use increases with latitude, with the range (between minimum and maximum) being smallest in Dunedin. However, as discussed earlier, the small number of schools in the Dunedin sample limits the value of this comparison. The two schools in Hamilton using oil have a tighter consumption per classroom range than the three schools in Wanganui. Such variations would form an important part of the analysis to be undertaken in an overall energy management programme.

This reemphasises the conclusions from the previous report (Ref 1) that there are potential savings if the wide variations in energy expenditure can be reduced. Care should be taken in interpreting the "minimum" expenditures as they could represent schools that do not achieve satisfactory comfort levels, or the incorrect allocation of energy expenditure. The proposed Schools Energy Database should be designed to permit such comparisons as part of an overall Energy Management Programme.

Recommendation : **The Schools Energy Database be designed to permit examination of variations in energy use between schools.**

2.2.5 Light, Heat & Water Changes Year by Year

As discussed earlier, the separate detailing of Light, Heat & Water expenditure by fuel type has only been required from Secondary School annual accounts since the 1984/85 financial year. Although all this information is now available in a LOTUS123 spreadsheet, and on the Victoria University IBM 4341 mainframe computer, a full analysis of changes between years has not been made. For example, if there is a sudden change in a school's annual Light, Heat & Water expenditure that cannot be explained by changes in fuel prices or building changes, then further investigations should be undertaken.

Recommendation : **Analysis be undertaken to compare changes between years of Light, Heat & Water expenditure to determine patterns for subsequent use in the Energy Management Programme.**

2.2.6 Capital Expenditure vs Running Costs - Integrated Schools

Integrated Schools represent the ultimate separation between capital expenditure and running costs. It is our understanding that while the Department of Education pays the running costs (including Maintenance and Light, Heat & Water) for Integrated Schools, capital costs are the responsibility of the schools' owners.

Although no Integrated Secondary Schools spent over $40,000 on Light, Heat & Water in 1985/86 (Table 6), one Integrated Secondary School (Sacred Heart Girls College) is included in the list of

1985/86 LIGHT, HEAT & WATER EXPENDITURE

By Department of Education
City District

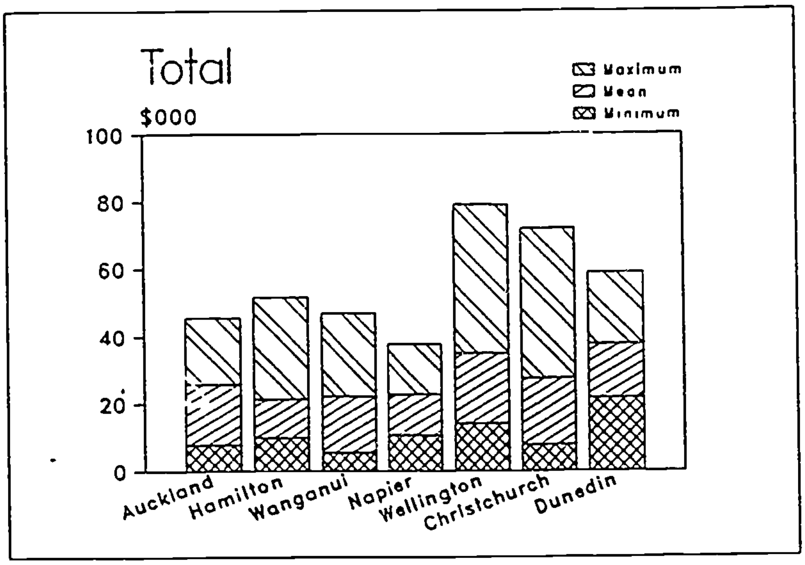

Figure 17

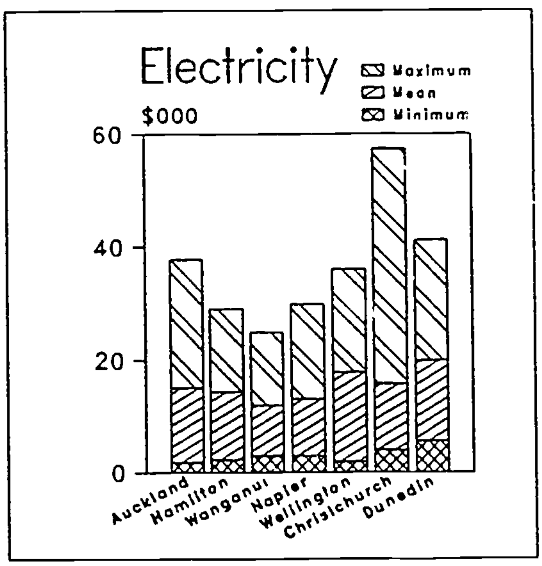

Figure 18

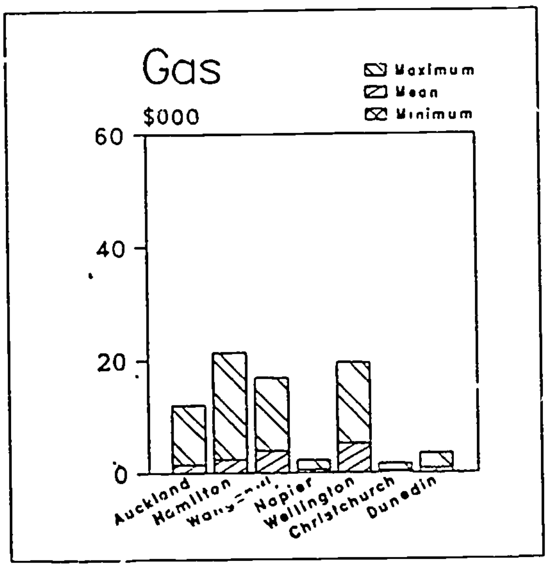

Figure 19

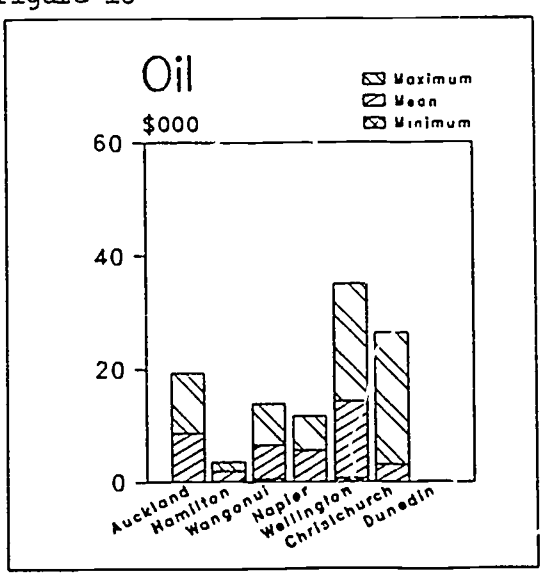

Figure 20

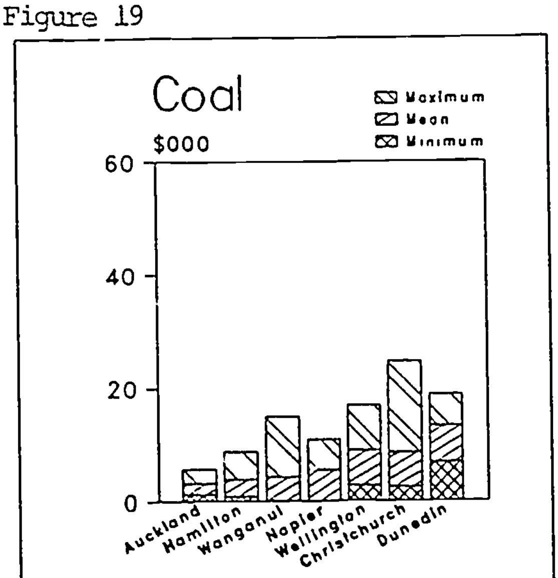

Figure 21

1985/86 LIGHT, HEAT & WATER EXPENDITURE PER CLASSROOM

By Department of Education
City District

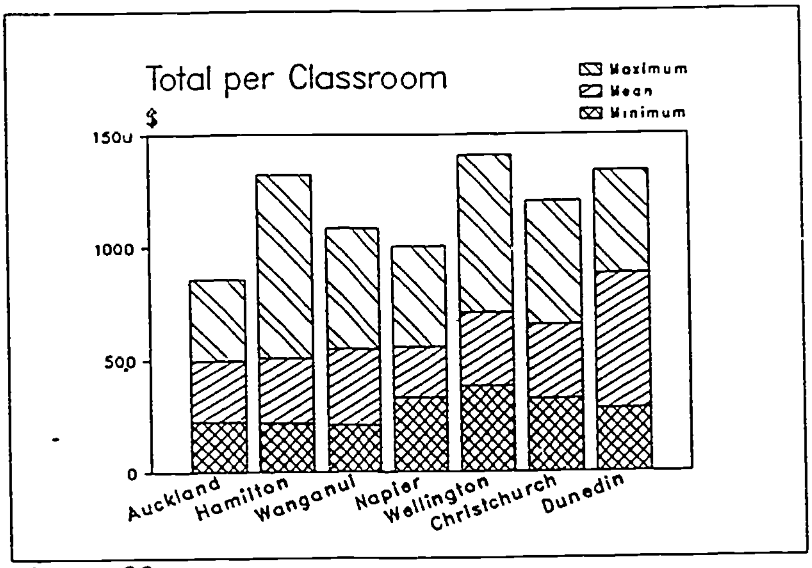

Figure 22

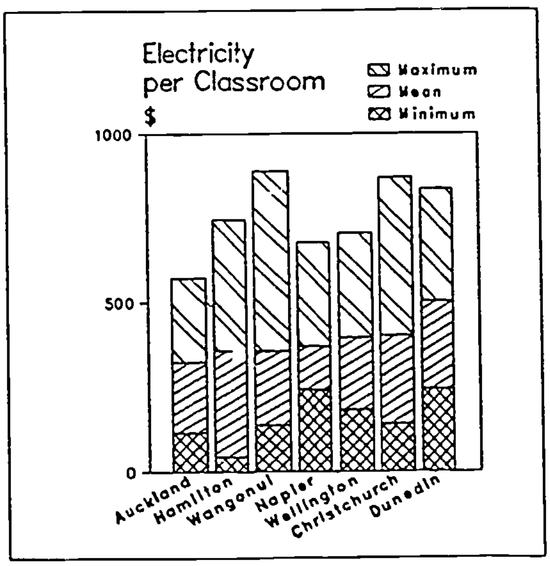

Figure 23

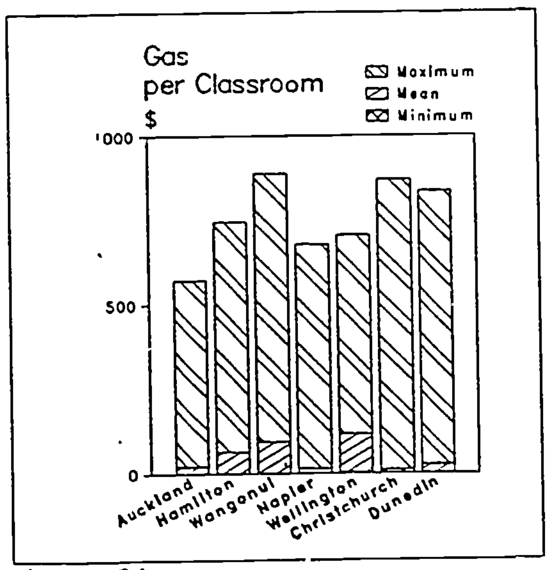

Figure 24

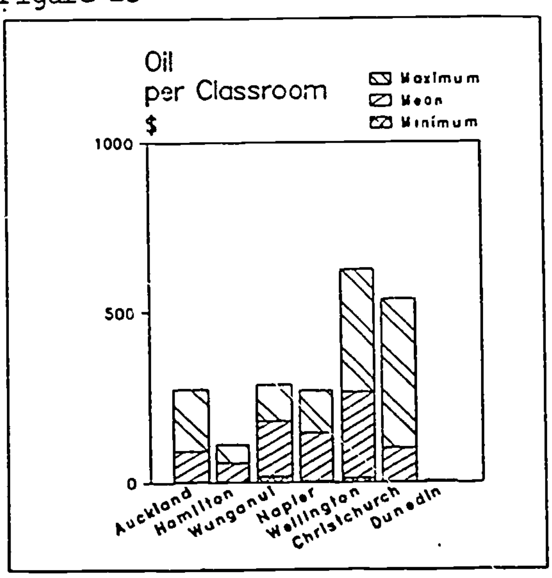

Figure 25

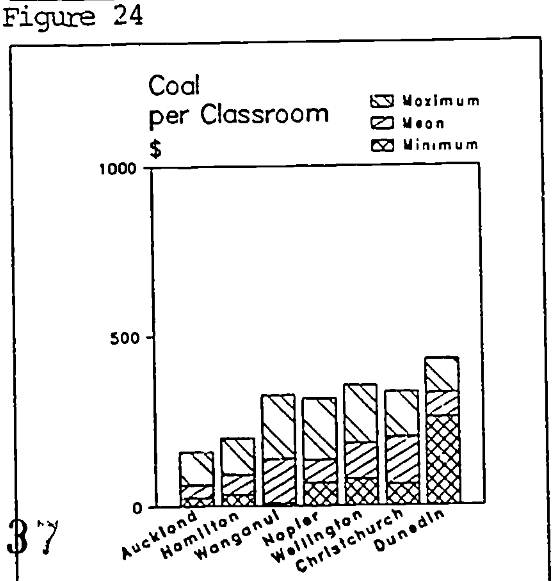

Figure 26

schools spending over $800 per classroom (Table 7). In the Wellington region one Integrated Secondary School has the highest expenditure on electricity per classroom (see Section 4.1.2). This may be due to the use of electric heating which is low in capital cost, but has high running costs.

Analysis of Light, Heat & Water accounts for 1985/86 is limited by the number of annual accounts lacking individual fuel expenditures for Integrated Secondary Schools. Therefore this analysis is limited in scope, but may be indicative of greater problems. Further investigations should be undertaken into whether Integrated Schools spend more on Light, Heat & Water than other schools in their region, and if so what remedies are available.

Recommendation: **Further investigation be undertaken into Integrated Schools' Light, Heat & Water expenditure.**

3. INDIVIDUAL SCHOOL ENERGY USE INFORMATION

The prime purpose of energy use in schools is to provide a comfortable environment for pupils and staff. Energy use management must maintain this orientation by providing for people's needs, not just reducing the cost of lighting or heating the buildings.

The central Department of Education accounting system can provide information on the cost of energy in secondary schools for a full year, but neither the district nor the school accounting systems track the pattern of energy expenditure throughout the year. In particular there are no links between expenditure on energy and expenditure on maintenance or capital works. For example, no mechanism exists to compare energy expenditure and the physical state of the boilers, pipes or lights.

3.1 Financial Data

Energy accounts are currently handled as part of the normal Department of Education financial management process but important information concerning energy use is lost. This loss can be due to changes in the cost of energy, either on a time or district basis, or the merging together of supplies into a single bill. The authors of this report have invested a large amount of time in extracting such detailed energy information from central records of school accounts, checking and analysing. For a routine Energy Management Programme to be effective, procedures must be introduced to reduce the need for such an investment of time.

The following section examine the current Departmental procedures for the collection of financial data related to energy consumption, detail the collection approach we adopted and make recommendations as to data collection for an Energy Management Programme.

3.1.1 Departmental Accounting System:

Financial management systems collect, use and store data that relates to financial transactions. As a result information of importance to energy management is discarded. In particular energy bills are recorded as dollars, with no details of the date(s) of supply, quantity and type of energy purchased. For analysis to be based on standard financial summaries, from different schools and energy suppliers, assumptions must be made as to unit energy costs (see for example Ref 1).

Payment accounting systems are set up to deal with the payment of bills (debits), and to a more limited extent provision for overpayments (credits). Energy supply meters can be (and sometimes are) misread. Payment systems will swiftly deal with a bill many times larger than average, and then not pay the supplier again until the overpayment is used. It may then be some time before a bill based on a correct meter reading is paid, and stored in the archived bills. As discussed in Section 3.1.3, it is our experience in extracting energy information from archived invoices and bills, that unless both credit and debit notes are kept, considerable additional effort is required to determine actual energy use patterns.

Recommendation : Credit notes to be archived with cheque or payment records.

3.1.2 Schools Energy Database

The previous study report (Ref 1) based its analysis on energy data extracted from financial accounts. The current project organised that Light, Heat & Water financial data, plus more recent data on selected schools, into a coherent, consistent database. The necessary computing work has been carried out and the data put into SAS datasets stored on the Victoria University IBM 4341 mainframe. This detailed energy use database proved invaluable in the detection and rectification of problems in the individual school case studies discussed in Chapter 4.

Together these two databases form the crude basis of a Schools Energy Data Base.

Appendix I provides a sample listing for one school. A list of schools for which energy bills have been obtained is also given.

A full Schools Energy Database would also include information on the age and type of boiler and heating distribution system, room heaters, physical layout of the school, which rooms are serviced by the boiler or by unit heaters etc.

3.1.3 Data sources

Energy billing information was obtained for Wellington primary schools from the Wellington Education Board (W.E.B.), and secondary schools under the control of the Wellington Secondary Schools Council and the Christchurch Secondary Schools Council:

Primary Schools - W.E.B. data was provided in the form of a computer printout covering the 1984/85 financial year. This data was then loaded onto the Victoria University mainframe computer in SAS datasets.

Secondary Schools - Visits were made to the Wellington Secondary Schools Council, and the Christchurch Secondary Schools Council. Including the information from the previous study, bills for these councils dating back to 1980 are now available in a database form. All bills are in SAS datasets, and in addition billing details for the schools investigated in 1986 are in a LOTUS123 spreadsheet form. Full details on the methods used are given in the previous report (Ref 1), but for completeness a brief summary is given here.

Considerable time is required both to correctly transcribe all the bill information and to ensure that all energy bills have been detected. For example one person (with no other duties or responsibilities) took 14 hours to record six months of billing information for seven Christchurch schools on tabulating forms.

Invoices are paid by Councils in a time sequence, with bills batched by arrival date, and paid on a regular cycle e.g. weekly. The bill, bearing the required approval signature, is then stored in a cardboard file in an archive store. E.R.G. personnel visited each Council and sorted through all archived invoices and energy bills. The information from the energy bills was then extracted and either loaded directly into LOTUS123 on a Portable IBM PC computer or transcribed onto tabulating forms for loading at a later date.

The tabulated lists were checked to ensure that a continuous cover for the time period was achieved. In the case of electricity and gas bills, both the previous and present meter readings and dates are given. If a bill was missing, another check of the files for that month would be made. Then the most recent previous bill's "present" meter reading and date would be compared with the bill under investigation. If the meter readings agreed, even though the dates did not, then it could be assumed that no energy had been used. If this was not the case, then a check was made for a payment "Credit" on the bill. If the amount of "Credit" and the energy consumption calculated from the difference between the last "present" and the current "present" meter reading appeared reasonable this information was used. If not, a check was made to determine if any of the bills had been based on estimated readings (i.e. the meter had not actually been read and the energy supplier had "estimated" consumption based on some formula).

In some cases the discrepancy could be traced to incorrect meter readings or estimates creating excessive bills. If the following bill was based on a correct, or actual, meter reading a large "Credit" may have been given. In this case until that credit had been used by supplied energy then no bill would be stored in the archives system.

For fuels delivered in bulk, i.e. coal, oil or wood, invoices show only the date of delivery and amount. The following assumptions have been made for energy consumption to be calculated per day based on delivery invoices:

(i) <u>Fuel storage is empty at the start of the heating system;</u>
Caretakers seem to prefer to have coal bunkers empty at the end of the heating season to permit any required maintenance to be carried out. This also means the boiler house is clean over the summer. The same is not true for oil tanks, but no measurement is made of the quantity in the tank.

(ii) <u>All fuel delivered is consumed by the next delivery date;</u>
School coal bunkers tend not to be large, and coal deliveries are regular, often fortnightly.
Oil tanks tend to be filled on a regular truck route, perhaps weekly.

(iii) <u>Heating season ends on 1 November.</u>
Delivery dates are easily determined, but the weather and school requirements determine the finishing. 1st November was chosen as a typical ending date.

The greatest errors in analysis will occur at the start and end of the heating systems. Lesser errors are to be expected with respect to oil use during the heating season. Given these constraints, it was considered that these assumptions offer a consistent framework for analysis .

3.1.4 Data Processing
It was found that even with careful data entry (double keying was not used) obvious data errors occurred. These could have occurred either at the initial recording of energy and cost data onto tabulating forms, or at computer data entry. It was decided that the

best approach, considering the large amount of data, was to develop automated checking and correction procedures.

The assumption was made, based on extensive examination of the data and the fact that expenditure is audited, that data errors were likely to involve incorrect energy, rather than financial, data. The approach taken was:

(1) group fuel types by years;
(2) calculate the cost per energy unit;
(3) determine the 25th and 75th percentiles for all schools;
(4) if the cost per unit was greater than double the 75th percentile or less than two tenths of the 25th percentile for that fuel in that year, alter the number of units to give the cost per unit as the 50th percentile (i.e. median).

i.e. 2 * 75th percentile < Acceptable cost per unit < 0.2 * 25th percentile

Any changes were noted in the data file and a printed record was also made to ensure an audit trail was available if required.

3.1.5 Data Checking - Results

Only a few changes following checking were required for data specifically collected for this study - of the 4356 bills recorded for seven Wellington and five Christchurch secondary schools for the years 1977 through 1985, 25 bills (0.57%) required alteration due to obvious data errors, while 14 bills (0.32%) required calculation of missing values.

W.E.B. has been recording energy data in addition to standard accounting data for at least eight years. As billing data is entered, the computer checks the entry category, and for energy categories requests energy use data. Unfortunately the audit system only covers financial details, and thus the energy unit information is not checked for errors. For the 1984/85 year, 2830 bills were recorded for 294 schools in the W.E.B. region. On examination, 146 of the recorded energy amounts (5.1%) required alteration due to obvious data errors while 470 (16.6%) required the energy use to be generated to complete missing data.

3.1.6 Data collection

It is possible to record energy use information at the same time as bill payment information is loaded into the computer, given suitable software. This would pick up problems of the type reported by W.E.B. where, due to operator error, one entire month's energy data was incorrectly entered. This was not discovered until after the end of the month when the monthly analysis had been prepared and the data had been removed from the computer onto tape storage. The W.E.B.'s present accounting software does not permit such errors to be corrected. For energy data to be of reliable quality and hence to provide useful energy management information, it is necessary for the energy data to be given the same audit check (possibly double keying) as the financial data.

Recommendation : **Energy data be recorded, and checked, at the same time as financial data in all computer based school accounts systems.**

3.2 Physical Information

The physical layout, construction or location of the school buildings and services is not as well documented as the financial information. In the next few pages we examine the types of data that are available and make recommendations for improved data collection and management.

3.2.1 School Inspection and Plans

Almost without exception, obtaining plans or detailed up-to-date building information on secondary schools proved a difficult task. Plans might be kept in the school storeroom (along with lost raincoats, shoes and other miscellanea), at the Regional Office or not at all. Where M.W.D. has carried out design or construction, plans were stored. Even if plans were kept, whatever the location, they were highly unlikely either to be "as built" or even up to date.

Recommendation : **An up-to-date register of building plans be maintained in each school. A condition of any maintenance, upgrading, construction or other significant work contract is for these plans to be upgraded. The register should be supervised by the Headmaster, Executive Officer or Caretaker.**

At Rongotai College an "Owners Manual" for the heating system was found. It had been prepared when the heating system had been upgraded and consisted of photocopies of the manufacturer's literature on each component of the heating system. At the front a list of instructions on the care and maintenance of the heating system was provided. The caretaker had carefully put the folder containing the manual in a safe place, and as a consequence it was unavailable for use in the day-by-day running of the heating system.

The new control panel at Cashmere High School, installed during the period of study, included a one page set of instructions mounted behind a sheet of clear perspex. Such an approach would ensure that even if the caretaker changes, or is ill, another person can operate the system to the standards expected by the designers. If the operation of the system changes through repair or modification then a new set of instructions must be provided.

Recommendation : **All school heating systems be provided with a brief (e.g. 1 page behind a clear, water proof, plastic cover) set of instructions mounted in the boiler house for ready use. Changes to the heating system operation must result in changes to the instructions.**

In the schools inspected in Christchurch where old control panels had been replaced, new panels including flow mimics had been provided. The flow mimics provide a schematic of the heating system with lights serving to indicate operating valves or pumps. In Hillmorton and Burnside High Schools school plans with switches mounted on the plan by the respective buildings were used to set the heating system controls for night classes. Caretaker comment was favourable, but it was apparent that errors and changes between the drawing of the mimics and the present time had somewhat diminished their value.

At Linwood High School a "Main Pump" shown by a light on the mimic board indeed indicated, correctly, the operation of a pump relay. However the pump had been removed so the mimic light was pointless. It should be recognised that funds will have to be spent on maintaining control panels to ensure satisfactory long term operation of the heating system.

No central register of school buildings, heating systems, or maintenance programme has been sighted, nor does one appear to be maintained within the Department of Education.

Recommendation : **Management information on the existing Department of Education building stock must be in a more accessible form.**

Such information would not only highlight how many buildings of one type have been constructed, but also enable forecasts of maintenance or replacement demands and scheduling to spread the costs. For example, assuming a useful lifetime of 30 yea or boiler controls, then systems installed in the 1960's are now due for replacement. Heat distribution systems also have finite lifetimes. It has already been found in Christchurch that the insulation on one type of underground piping is failing requiring replacement. It is likely that a central register would assist the more effective management of all building resources - not just of building energy use.

For the long term management of the limited maintenance funds, it is essential that close control be kept not only on the immediately obvious costs, but also over planning for replacement (Ref 4). Such a register should be maintained regionally, but be available to the section of Head Office responsible for energy management.

Recommendation : **An annually updated, standard format, register of key facts on each school be maintained by the service responsible for maintenance (i.e. Regional Office or Education Board).**

3.2.2 Uses of S.E.D.A.B.

One benefit from the collection and collation of bill details for both energy and cost, is the identification of unexpected problems. Although the current project has not been concerned with ensuring the application of the correct energy supply tariff, it was interested in the pattern of energy use over the year. Examination of energy billing information for the 13 schools for which bills were collected, found two schools (15%) with electricity meters for which supply charges are being paid, but no electricity used. Although the absolute savings from each meter are small, rectification is low in cost with short payback.

a) Rongotai College, Wellington - M.E.D. Account 35537/0003, Meter number 19258.

Apparently some years ago the local slot car club made use of the previously disused hall. A separate electricity meter was installed, and the club paid for the electricity it used. When the club stopped operating the meter remained but since 1980 the records collected by this study show no energy has been supplied through the meter. The "Daily Supply Charge" of $0.24 equates to a cost of $88 per year.

b) Cashmere High School, Christchurch - M.E.D. Account 944157, Meter number 5930910.

Prior to the construction of the new caretakers house, electricity was provided to the house by a separate line brought in from a nearby side street. Electricity was also provided to a small pump for use in irrigating the playing fields from the local stream (a tributary of the mighty Avon). When the caretaker's house was demolished, the pump remained under separate metering. According to the school's Executive Officer, experiments had found there was insufficient water in the stream to irrigate the fields, and it was not used. Bills from 1981 on, show no electricity use but an ongoing supply charge of $14 per billing period, or $84 per year.

Recommendation : **Energy bills that are subject to only a minimum charge for more than 12 months be investigated. Where possible, alternative arrangements for supply should be made or the supply disconnected.**

4. INVESTIGATIONS

Table 9 lists the individual secondary schools inspected by this project, the type of monitoring undertaken and some information on the energy use and comparison with other schools nationally and in the same city. The investigations carried out in the winter of 1986 were concerned with demonstrating that energy savings could be both identified and achieved. Investigations were only undertaken in two cities - Wellington because of its proximity to the Energy Research Group's base, and Christchurch as it is a flat city with a cooler climate. Christchurch is located on a flat plain, unlike hilly Wellington, and is therefore less subject to wide variations between local microclimates. It therefore permits ready comparison of energy management activities between different schools which can be expected to be subject to the same weather conditions.

There is nothing to indicate that school heating problems or energy use in these two cities are not representative of schools elsewhere in New Zealand.

Prior to the initial visit to the school, a letter requesting permission was sent to the headmaster and, in some cases, to the school board. Contact was maintained with the E.O.(Buildings) in each Department of Education Regional Office. Meetings were also held with the Regional Property Supervisor in each Regional Office. No work was carried out on any school without permission from the Department of Education. In practice this involved discussion with Head Office, Regional Office E.O.(Buildings), Property Supervisors, school Executive Officers and school caretakers. In addition officers from Head Office and Regional Office were taken to the schools under study, and the project activities demonstrated.

Considerable assistance was obtained from M.W.D. The Mechanical and Electrical Engineering Directorates (M. & E.) in both cities organised site visits, and in Wellington undertook full energy audits. Property Management Group (P.M.G.) staff in both cities assisted with the site visits, and the implementation of recommendations. Communication difficulties were caused by the requirement during the project for M.W.D. to charge for all services, but these were resolved satisfactorily. It should be noted that future energy management investigations, unless carried out under the Government Building Energy Management Programme (G.B.E.M.P.), will have a cost to the Department of Education.

Table 9 : SCHOOLS INVESTIGATED - WINTER 1986

School	Logger Monitor		Temperatures		Meters	Other Information			Size		Light, Heat & Water Cost	1985/86 Rankings			
	Switch	Energy	Outside	Inside	Run hour Meters	Bills	Min/Max Temp	Date	Classrooms Perm	Classrooms Temp	TOTAL $	REGIONAL TOTAL	REGIONAL /CR	NATIONAL TOTAL	NATIONAL /CR
Wellington															
Newlands Coll.	-	-	-	-	-	Yes	-	-	36.5	6.0	27668	23	29	89	64
Onslow Coll.	-	-	-	-	-	Yes	-	-	45.0	4.0	41590	9	10	19	26
Rongotai Coll.	Yes	Yes[1]	Yes[1]	Yes[1]	-	Yes	-	2 Oct	44.0	5.0	46527	5	5	11	10
Wellington Coll.	Yes[2]	-	-	-	2 oil	Yes	-	-	47.0	9.0	78914	1	1	1	1
Wellington East	-	-	-	-	-	Yes	-	-	34.0	12.0	27158	33	34	94	84
Wellington Girls	Yes	-	-	-	-	Yes	-	-	37.0	14.0	32715	20	24	56	67
Wellington High	-	-	-	-	-	Yes	-	-	44.0	7.0	47429	6	3	9	14
Christchurch															
Cashmere H.S.	Yes[4]	Yes	Yes	Yes	2 coal	Yes	-	10 Jul	59.0	2.0	29813	20	30	71	124
Hagley H.S.	-	-	-	-	2 oil	Yes	-	-	38.0	11.0	56866	4	4	5	6
Hillmorton H.S.	Yes	Yes	Yes	Yes	2 coal	Yes	-	12 Jul	52.0	2.0	24516	26	34	110	139
Papanui H.S.	Yes	-	Yes	-	2 coal	Yes	Yes	-	59.0	8.0	35114	15	28	41	111
Kaiapoi H.S.	-	-	-	-	2 coal	Yes	Yes	-	31.0	7.0	34195	16	10	46	17
Linwood H.S.	Yes	-	-	-	-	Yes	Yes	-[3]	58.0	15.0	33631	17	33	49	133

Notes

1 Rongotai College - Energy recorded from 12 June to 28 July 14:45 before compensator valve. Sensor then moved to after valve.
- Outside Temperature recorded from 11 June.
- Inside Temperature recorded from 2 July.

2 Wellington College - Switching recorded from 23 June to 29 August but continuous boiler operation.

3 Linwood High School - Optimiser installed prior to this project. Non-self-adapting.

4 Cashmere High School - No relay monitoring boiler permission to run. Assume boiler on when pumps on.

Explanation of Headings

Logger Monitor — Data logger monitored:
Switch - boiler and pump switching.
Energy - energy used by school from temperature difference between flow and return water.
Outside - Air temperature outside boiler house.
Inside - Air temperature in nearby classroom.

Meters — Runhour meter on boiler.

Other Information — Bills - Bills loaded into LOTUS123.
Min/Max Temp - Minimum/Maximum thermometer in a classroom.
Date - Optimiser installed and running.

Size — 1985 Permanent and Temporary classroom.

Light Heat Water — Cost - 1985 total.
TOTAL - Total Light, Heat & Water.
/CR - Light, Heat & Water per classroom.
1985/86 Rankings - based on schools in region/nation for which $LHW data available:
Wellington - C.R.O. = 85 schools out of 103 (83%)
Christchurch - S.R.O.= 57 schools out of 82 (70%)
National = 256 schools out of 318 (81%)

4.1 Wellington Secondary Schools

The following sections outline the approach and the investigations undertaken in each school. The work on Wellington secondary schools has involved:

(1) the selection of schools;
(2) inspection and energy audits carried out by the Ministry of Works and Development under G.B.E.M.P.;
(3) the preparation of recommendations;
(4) discussion with and approval from the Department of Education;
(5) implementation;
(6) and monitoring.

4.1.1 Hypothesis:

Primary: The use of some method of preselection will result in greater opportunities from improved energy management.

Secondary: Indexes of total Light, Heat & Water and per classroom Light, Heat & Water expenditure provide a suitable basis for an Energy Management Database for the Department of Education.

4.1.2 School Selection

Information was available to permit the preparation of indexes for 85 of the 103 secondary schools (83%) in the central region. Table 10 ranks the schools by expenditure on any one energy type giving the expenditure and rankings on a Total and Per Classroom basis.

Table 10: C.R.O. SCHOOLS RANKED BY 1984 FUEL EXPENDITURE

	Individual Fuel					LHW
			Fuel	Per Classroom		Total
School	Type	$	Rank	$	Rank	Rank
Wellington College	Elect	29994	1	600	2	1
Wellington College	Oil	21654	1	434	1	1
Wellington High School	Elect	21294	2	394	5	2
Waimea College	Elect	20281	3	328	9	8
Otaki College	Elect	18581	4	534	3	16
Wairarapa College	Elect	17854	5	368	7	3
Nelson College	Elect	16508	6	308	10	11
Rongotai College	Elect	16354	7	300	11	4
Rongotai College	Gas	14654	1	268	1	4
Nelson Girls College	Elect	14574	8	408	4	27
Porirua College	Coal	14414	1	214	4	12
Chanel College	Elect	13621	9	620	1	30
Wellington Girls Coll.	Elect	12521	10	268	12	13
Parkway College	Coal	11594	2	300	1	17
Tawa College	Gas	11428	2	174	5	7

Queen Charlotte Coll	Elect	8481	22	388	6	40
Golden Bay H.S.	Elect	7454	26	348	8	41

Source : Department of Education data.

Thus, for example, Table 10 shows that the school with highest fuel expenditure in the Wellington region is Wellington College for electricity. It also ranks first for total Light, Heat & Water expenditure in the Wellington region, first for schools that use electricity, but second for electricity expenditure per classroom. The school with the second highest fuel expenditure is also Wellington College, but in this case the fuel is oil.

Electricity is a high cost fuel, and it is perhaps not surprising that 10 of the top 15 schools ranked by fuel costs are listed due to electricity costs. For the Wellington schools providing individual fuel expenditures only Chanel College, an Integrated School, reported only expenditure on electricity, thus using it for heating.

All the schools in the top 15 listed by fuel are also in the top 15 ranked by fuel use per classroom except for Porirua and Tawa Colleges. Queen Charlotte College and Golden Bay High School are not in the top 15 of fuel expenditure, but they are in the top 15 ranked by fuel use per classroom, and are given at the end of Table 10.

Wellington College, as shown in Table 10, ranked the highest for both indexes and was selected for this work. Wellington Girls College, a sister school, was selected primarily because it has an identical main block. Its heating fuel (natural gas) expenditure (1984 $10,700, $228/classroom) does not rank highly enough to be included in the top 15 table for fuel expenditure. Wellington Girls College does rank second in gas expenditure per classroom. The third school selected for detailed investigation, Rongotai College, ranked first for natural gas expenditure.

4.1.3 Inspection and Energy Audit

In conjunction with the M.W.D. Wellington District M. & E. working through the G.B.E.M.P., full inspections and energy audits were made of the three schools.

Each audit consisted of a walk-through inspection by two engineers checking all energy using equipment - including boilers, room heaters, lights, lifts etc. Load monitoring was undertaken to determine the likely electricity end uses, and opportunities for savings. A breakdown of energy use and cost by end use and analysis of boiler fuel use and climate were provided by E.R.G.

In addition boiler combustion efficiency tests were undertaken.

A list of recommendations for action was prepared and supplied to E.R.G. for transmission to the Department of Education.

4.1.4 Experiment Statement

(1) Primary: Investigate the selection of cases using a database approach
(2) Secondary: Determine actual savings possible in selected schools through an energy audit and implementation of recommendations coupled with intensive monitoring.

4.1.5 Results

Discussions were held with the Department of Education over the recommendations, and where agreed the recommendations were implemented. These actions will be discussed in detail for each school, but it is worth noting that only those recommendations that could be implemented immediately were undertaken. Even so, some time lapsed between the agreement to proceed and the implementation.

All work was carried out by M.W.D. Wellington District P.M.G. with assistance from Wellington District M. & E.

Table 9 summarises the monitoring undertaken in Wellington and Christchurch schools. This monitoring was started as soon as possible in order to provide a reference base. Unfortunately a number of datalogger failures at the start of the monitoring has reduced the amount of reference base information, and only limited comparisons are possible for this report. Comparisons between heating seasons with and without the improvements will be possible after the 1987 heating season, and permit a better determination of potential savings.

Recommendation : **Energy bills for the schools monitored in 1986 be analysed for the 1987 heating season, and compared to earlier seasons to determine the actual benefits from changes instigated by this project.**

Extensive software development was required to convert datalogging output into an analysed form. The datalogging programme was designed around one type of datalogger - Solid State Equipment TASMAN series. These are now obsolete, although E.R.G. was fortunate in being able to obtain, at no rental cost, dataloggers from the Department of Geography, V.U.W., the D.S.I.R. Geological Survey and Massey University Department of Agricultural Engineering. Suitable software for downloading from the datalogger directly onto a Portable IBM PC was purchased from Solid State Equipment Ltd.

The objective in using dataloggers was to monitor school boiler operation, and then process this data into a form indicating use patterns, climatic conditions and energy consumption. Each datalogger channel was set up to monitor the same thing from school to school. A 200 line SAS programme was written to process datalogging data from all schools and a further 800 line programme to extract boiler and pump switching times (see Table 15 for example of output). In addition, all data was graphed to permit ready visual analysis and tracking of irregularities.

A summary report was also provided by M.W.D. Wellington District M. & E. on the modifications they undertook, and this is reproduced in Appendix II.

a) Rongotai College

A walk-through energy audit was undertaken on 6 March 1986.

Rongotai College had 54 classrooms, and a roll between 800 and 900 pupils. Most of the teaching space is in a main building with parts varying in age and construction. This is a two storey complex of connected buildings enclosing a rectangular courtyard and the main assembly hall. There are also separate buildings comprising three small teaching blocks, a gymnasium, a recreation hall and swimming pool with associated changing rooms.

The buildings in the main block are of heavy construction with large areas of glazing. Most spaces are naturally ventilated and naturally lit. There are three spaces with mechanical ventilation - the audiovisual room (B-13), a classroom (B-39) and the computer room with an associated heat-pump chilling unit. The heating system consisted of two 381 kW gas-fired hot water boilers controlled by a Satchwell system 565 electro-mechanical "optimiser". Pumps in the boiler room feed a distribution network of insulated pipes, some of which is in underground trenches. Other buildings have wall mounted, gas or electric, unit heaters. Gas heated water is provided for showers in the changing rooms. A gas fired pottery kiln was to be commissioned in 1986.

Figure 27 provides a breakdown of energy use and cost for 1985. Natural gas provided 79% of energy used in the school, but its lower cost meant that it was only 52% of the expenditure on energy. Electricity provided the remaining 21% of energy needs - pumps, lighting, swimming pool filtration, and other direct electricity uses including unit heaters - for 48% of the cost.

Figure 28 illustrates the consumption of electricity and natural gas on a per school day basis. The number of school days in the calendar date period covered by the bill was divided into the energy consumption. This approach assumes that energy is used in the school only on school days, and thus may be in error if either energy is used regardless of the day of the week or special activities take place on weekends or school holidays, but it provides a common basis for comparison. It may be seen that significant gas consumption occurs outside the normal heating season (mid-April to late October). It would be expected that if the heating controls were operating correctly they would control gas consumption against outside temperature.

The performance line in Figure 29 plots gas consumption per school day against average school day temperature over a 28 month period. Temperature data was provided by the N.Z. Meteorological Service without charge. Each circle represents one gas bill. A best fit line through the points would have a negative slope (i.e. increasing average temperature resulting in a decrease in energy use), and the data points lie close to the line. The wide scatter shown in Figure 29 suggested that the system controls were not working well.

Figure 28 also shows that variations in electricity consumption are less marked than for gas. The increase in daily consumption in the April 1985 to June 1985 period is caused by the use of swimming pool filtration and chlorination pumps.

A monitoring programme examining boiler and pump switching, exterior and interior air temperatures and the heating water flow/return temperature difference began on 27 May 1986 with preliminary testing. Initial analysis suggested datalogger failure as no boiler or pump switching was detected. A further trial from 30 May to 9 June 1986 confirmed the correct operation of the datalogger, but revealed that the boiler was running 24 hours a day. It was also noted that the heater control in the Audiovisual room was turned on at 4.30 pm one afternoon, and not turned off until the next morning. This control was found to override the boiler room controller. Full datalogging commenced fully on 12 June 1986 and ran continually for five months, with data being downloaded onto a Portable IBM PC every 4 days.

A

REPORT ON

AN ENERGY MANAGEMENT PILOT STUDY

CLOSING THE LOOP - IMPROVING ENERGY MANAGEMENT IN SCHOOLS

ABSTRACT

This report describes a study of the energy savings potential in New Zealand schools. It demonstrates that with simple payback times of less than two years, considerable reductions in expenditure on energy can be achieved with no reduction in comfort. It shows that failure to close the information feedback loop between those who pay the operating bills and those who are responsible for maintenance can lead to unnecessarily high running costs. It is suggested that this is due to an absence of any person with responsibility for energy management.

A selection technique based on energy expenditure and the number of classrooms in the school is described and used to select a number of schools for detailed investigation, and action.

Three Wellington and four Christchurch schools were monitored with electronic dataloggers during the winter of 1986, both before and after action had been taken to improve energy management. In all cases remedial work was cost-effective, with pay back times of not more than 2 years and in some cases of a few months. Savings in heating fuel costs through improved management ranged from 30% to 50%, far exceeding original estimates.

Techniques used included: walk-through energy audits, replacement of timeclock boiler controls with self-adaptive optimum start/stop controllers, runhour meters and repair of faulty controls.

Initial analysis found energy use did not correlate highly with exterior temperatures.

Recommendations for further action are given, and a basic approach to an improved energy management programme for the Department of Education is outlined.

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Client: DEPARTMENT OF EDUCATION

3 July 1987

RONGOTAI COLLEGE ENERGY USE

Energy Research Group Data

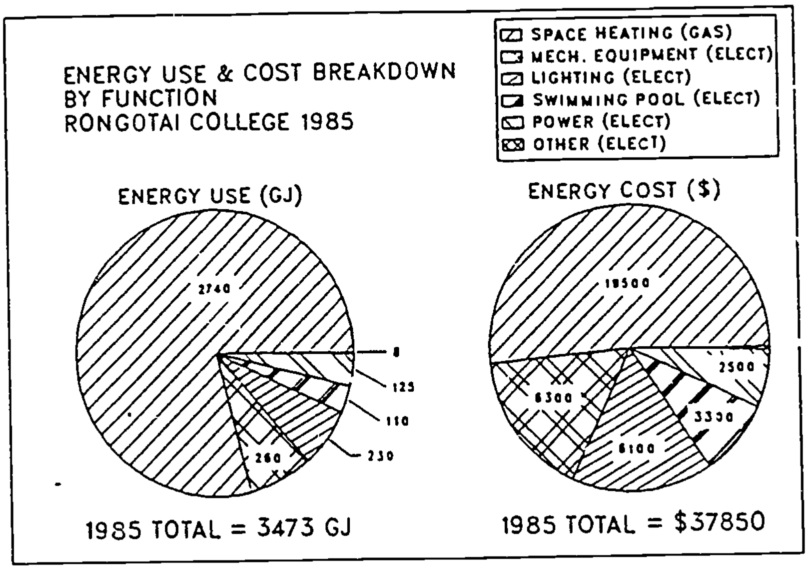


Figure 27

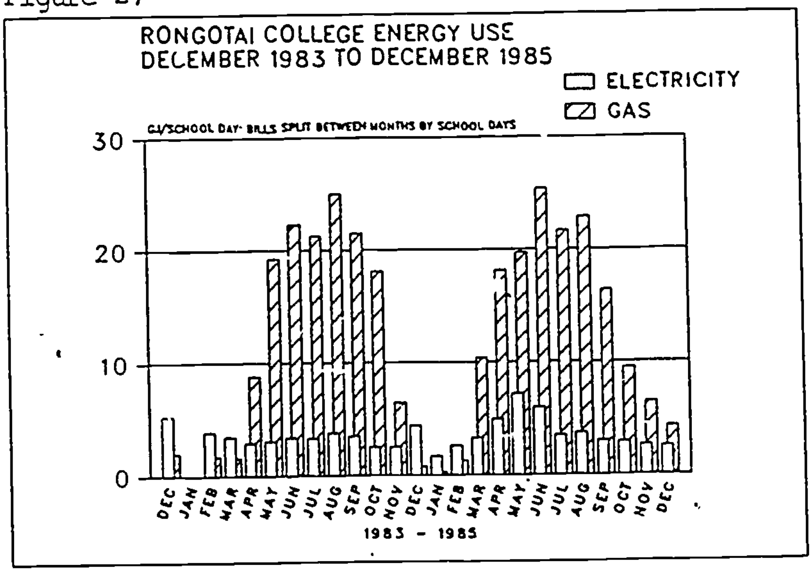


Figure 28

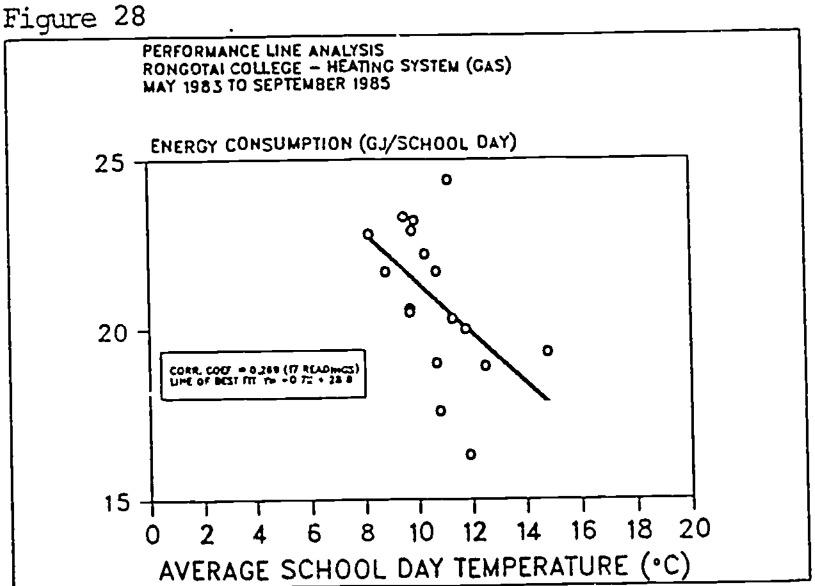


Figure 29

It was found that the boilers were running continuously throughout the heating season due to a faulty timeclock control. It appeared that the controller would work correctly for the first day after setup, but then never turned off. As there had been no complaints about the heating from school staff or pupils no action had been taken. There was also no feedback to either the caretaker or to those responsible for heating system maintenance from those who pay the gas bills.

Replacement of the timeclock control by a microprocessor based self-adaptive optimum-start/optimum-stop controller (termed an "optimiser") immediately resulted in savings. Figure 30 graphs the gas energy use per hour, making allowance for varying outside temperature, for five consecutive winter gas bills. The optimiser was commissioned on 2 October 1986, and thus affects two bills. The large increase in energy use per boiler runhour (left bar) can be explained by the need to heat the buildings after the nighttime and weekend cooling. Even so, the total energy used to heat the school indicated by the energy use per day-hour (right bar), has been reduced by more than 80% over the period of the graph.

It is interesting to note that the only complaints about the heating system were when the control had been repaired, and the boilers were operating on a more normal regime. It would appear that staff had become accustomed to the buildings receiving all day heating. Further analysis of interior temperature datalogger records is required to determine whether there was any noticeable change in the interior conditions.

Recommendation : **Further analysis be undertaken of the datalogger records of interior temperatures to determine the effect of continuous boiler operation on room temperatures.**

The continuous running time of the boilers requires more frequent boiler cleaning to ensure peak operating efficiency, but due to a lack of knowledge about the boiler runhours, this was not occurring.

Table 11 summarises the M.W.D. audit recommendations which fall into two main groups:

(1) lower cost - undertaking maintenance that should have been required previously plus some limited energy management; and
(2) higher cost - improving the energy management of the building and the heating system.

Table 11: RONGOTAI COLLEGE - SUMMARY OF M.W.D. ENERGY AUDIT REPORT

Action	Capital Costs	Annual Costs	Annual Savings	Payback (Years)
Deferred Maintenance				
Window & door major maintenance	?	?	?	short
Recommission boiler controls	$2,000	-	?	short
and upgrade where necessary	$7,000?	-	?	?
Replace corroded pipework	underway	?	?	short
Energy Management				
Turn off boilers during public holidays	-	$50	$450+	0.1
Turn off boilers during school holidays & provide unit electric heaters for staff & electric heaters for staffroom	$2000-$3000	-	$1550-$1390	1.3-1.6
Provide airlocks on selected doors	$5,000-$10,000	-	?	
Replace on/off switches with timeclocks	$800	-	-	2-4
Swimming pool pumps off in winter	-	-	$1000-$2000	short
Lighting awareness campaign	-	$400	$600-$1200	0.7-0.3
Automatic lighting control	$4,500-$7000	low	$1350-$2000	3-5

By the end of the 1986 heating season the following measures had been implemented:
the optimiser had been replaced and recommissioned;
the compensator controls checked and recommissioned;
the boiler air/fuel ratios adjusted but cleaning left until the end of the heating season; and
a time switch fitted in the Audiovisual room to limit unoccupied running of the heating system.
In addition the swimming pool was not in use, and therefore the pump electricity demand was not present.

Examination of the logger record for boiler switching once the optimiser was installed found that the caretaker was not content with the optimiser control of the boilers and was changing it to suit his requirements. It is our belief that this action was in response to staff complaints.

Recommendation : That the Rongotai College optimiser be monitored for a further season to determine the actual operation and whether OPTIMUM START or STOP of the boilers is more important.

EFFECT OF SELF-ADAPTIVE OPTIMISER ON ENERGY USE

Based on Anaysis of Gas Bills

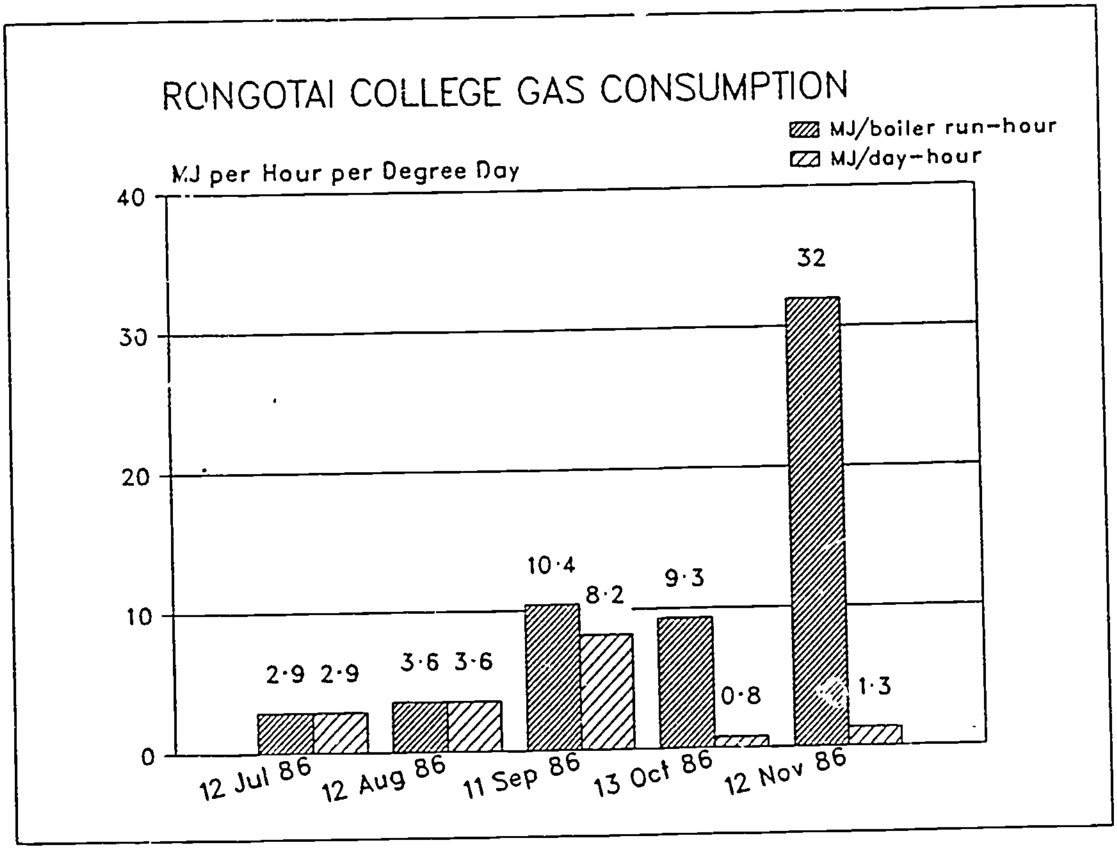


Figure 30

Notes:

- Gas consumption taken from regular bills.
- Boiler runhours calculated from datalogger switching records. Runhours here refer to the number of hours the boiler had permission to run (as opposed to other cases where runhour meters monitored the sum of time that fuel was supplied to the boiler)

The investigations undertaken in Christchurch into the use of optimisers was planned for schools that had been operating satisfactorily prior to the optimiser. In this case the school heating system was not operating correctly, and not all savings can be attributed to the optimiser. It is worth comparing the once only cost of installing the optimiser and undertaking checking of other boiler controls ($8000) with the annual gas savings ($19,000+).

No simple comparison can be made of the "pre-optimiser" and "post-optimiser" energy consumption due to the continuous running of the boilers "pre-optimiser". However the datalogger record provides an invaluable set of data on the behaviour of schools with, and without pupi' An initial examination of the data would appear to suggest that 'e daily energy supplied to the school is not very well related the "coldness" of the day, measured by degree days. Our previous study (Ref 1) monitored a Wellington primary school for two weeks, and found that energy use appeared to be more related to wind than temperature. The datalogger record for Rongotai College is unique in that it covers five months, four months of which the boilers operated continuously - school day, night and weekend. N.Z. Meteorological Service charging policy has now changed and a charge for climate data is now made. Thus additional funds are required for such analysis to be completed. Such an analysis could be invaluable in the future design, maintenance and upgrading of New Zealand schools.

b) Wellington College

A basic walk-through energy audit was undertaken on 14 March 1986.

Wellington College had 56 classrooms and a roll of approximately 1100 pupils. The majority of classrooms are located in a six storey tower block or associated S68 blocks. The heatir_ system consists of two oil fired HOVAL boilers installed in 1972 and located in the tower block penthouse under mechanical timeclock control. In addition, a number of temporary blocks are heated with wall mounted electric unit heaters. The tower block includes a library and staff room with limited cooking facilities. A student tuckshop is located in one of the temporary buildings.

Figure 31 provides a breakdown of energy use and cost for 1985. 35 Second Fuel Oil provided 62% of energy used in the school, for 49% of the energy expenditure. Electricity provided the most of the remaining 38% of energy needs (pumps, lighting, swimming pool filtration, and other direct electricity uses including unit heaters) for 51% of the cost. A small amount of natural gas is used for laboratories.

Figure 32 illustrates the consumption of oil, electricity and natural gas on a per school day basis. As discussed in Section 3.1.3, division into daily oil use is based on delivery dates and it is therefore difficult to make detailed analysis. The consumption patterns for each fuel throughout the year follow similar trends for both the years shown.

Figure 33 plots the performance line for oil consumption for a 17 month period. The correlation between energy use and temperature is not high, indicating potential problems with the boilers or controls.

WELLINGTON COLLEGE ENERGY USE

Energy Research Group Data

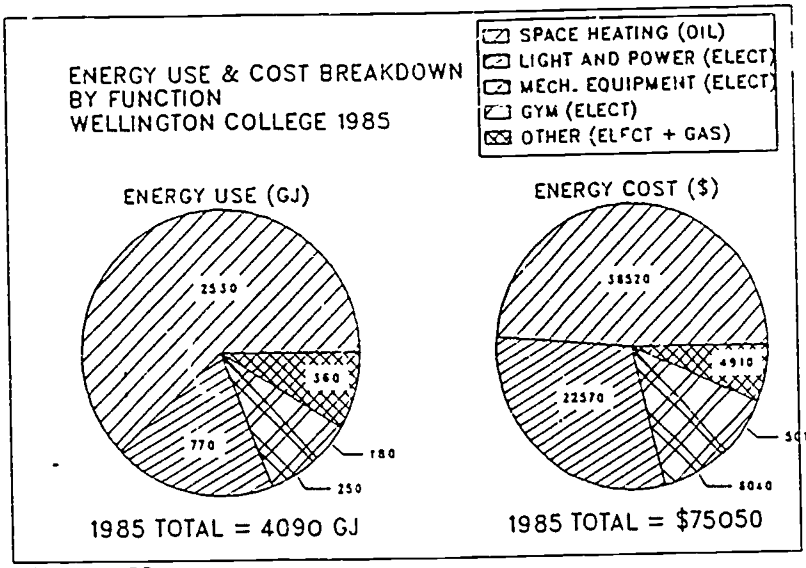


Figure 31

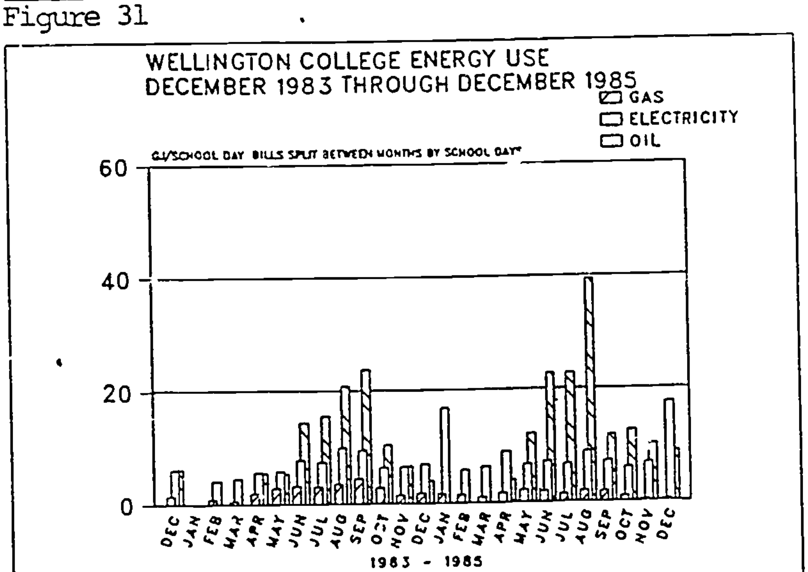


Figure 32

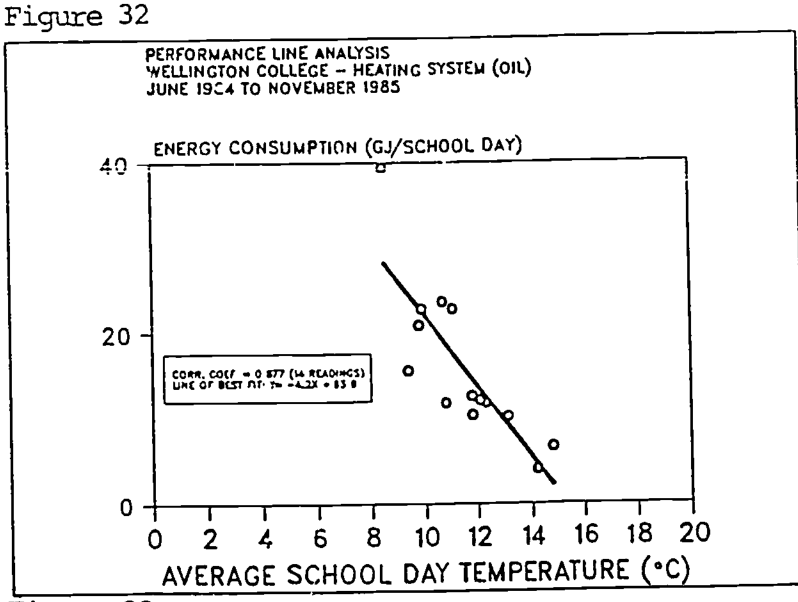


Figure 33

Prior to site inspection and the undertaking of a full energy audit, Wellington College was discussed with the maintenance contractors. It was reported that the school had regularly complained about problems with individual classroom heating, and regular applications had been made for funds to undertake a detailed investigation.

Table 12 summarises the M.W.D. Energy Audit report. It can be seen that although a number of energy management actions were recommended, the costs and annual savings were not quantified. The audit was undertaken without the benefit of datalogger monitoring. Additional investigation work was undertaken and is reported in the M.W.D. summary report reproduced in Appendix II.

Table 12: WELLINGTON COLLEGE - SUMMARY OF M.W.D. ENERGY AUDIT

Action	Cost	Annual Savings	Payback (Years)
Conversion of the boilers from oil to gas	$45-$55,000	$19,000	2.4-2.9
Repair of pneumatic controls in tower block	?	?	?
Timer switch control of room heater fans	?	?	?
Time switch over-ride for boiler control	?	?	?
Better control of out-of-hours electricity use	?	$12,000	?

The Energy Audit inspection found the boiler controls appeared to be working satisfactorily and even though the room thermostats were not operating heat was being delivered to the classrooms. Datalogger monitoring found that the boilers were operating 24 hours a day, regardless of timeclock operation. Discussions with the school staff indicated that the boilers were deliberately run continuously throughout the heating season to ensure the classrooms would be warm. The staff stated that they had found that insufficient heat was supplied to the classrooms if the boilers were permitted to switch off overnight, and thus the timeclock controls were overridden. Repair and replacement of faulty equipment is now estimated by M.W.D. to be between $NZ15,000 to $NZ30,000 - compared with the annual fuel oil bill of $NZ35,100, of which half could be assumed to be wasted.

Examination of Departmental files showed that the Inspecting Accountants "Inspection Report" carried out between May and August 1984 (Head Office File 376) had found a significant increase in oil consumption. Table 13, taken from that report, shows that water use increased by $10,161 or 516%, fuel oil use increased by $14,712 or 119% and Electricity use increased by $14,364 or 67%. Thus although the percentage increase was far larger for water, the actual cost increases for electricity and fuel oil were of greater significance.

Table 13: WELLINGTON COLLEGE - LIGHT, HEAT & WATER EXPENDITURE

Year	Electricity	Gas	Oil	Water
1980/81	$21,306	$1,220	$12,390	$1,971
1982/83	$28,515	$1,624	$28,828	$2,412
1983/84	$35,670	$2,272	$27,102	$12,132

Source : Inspection Report May to August 1984.

The Inspection Report states (p84) with respect to oil:

"The school is oil heated. The cost increase of oil per litre rose only two cents over the period 1980/81 to 1982/83. The E.O. offered as a reason for the large increase that the amount of the oil bills vary depending on when the tanks are filled."

and with respect to power:

"After querying the school it appears the reason behind the increase could perhaps be attributable to the building of the sports art centre. This is not separately metered"

Analysis of Fuel Oil invoices found that the average oil delivery was $3000, with a range of between $1,000 and $5,000. Thus the comment attributed to the school's E.O. would not appear to be correct.

The Inspection Letter requested comments on the increase in power use and water consumption. It did not mention the large increase in oil costs.

The table in the Inspection Report was marked:

"ATTENTION PROPERTY SUPERVISOR"

The C.R.O. file (File 7/19) showed a copy of the Inspection Letter that had been sent to the school had been forwarded to C.R.O. along with a supporting file note asking for the Property Supervisor to arrange for the college to carry out monitoring of water use.

Thus the current high heating expenditure is due to the Department of Education's failure firstly to detect that there was a high expenditure on heating and secondly to fund investigation into why insufficient heat was being delivered to the classrooms. It is also clear that the school was not unhappy with their solution (i.e. continuous boiler operation), and did not continue to attempt to have the heating system corrected.

The use of fuel oil for school heating is unusual in areas reticulated with natural gas. An "Investigation Report" was prepared by M.W.D. dated 12 November 1980 for the conversion from 35 Second Oil to natural gas or electricity. It concluded that the operating costs would be considerably lower using natural gas rather than electricity. A Department of Education programme of conversions from oil to alternative fuels was carried out in the early 1980's, but Wellington College was not converted. As part of this project, the recommendation was made for such a conversion to be again investigated. This has now been undertaken and a full proposal submitted by the M.W.D. to the Department. Due to the size and pressure of the gas pipelines in the school area, and the currently high total energy demand due to the boilers operating continuously, it is proposed to convert only one boiler, and retain the second boiler on oil until the problem of cold classrooms has been corrected. A payback period of under three years is expected for an expenditure of $29,000 (including G.S.T.) (see Appendix II).

Wellington College's expenditure on electricity is larger than on oil, as shown in Table 10. The electricity sub-mains from the main switchboard were monitored over a 10 day period from 24 July. The major energy loads are the canteen, the unmetered supply to the squash courts, the light main, the mechanical plant main (air compressor, circulating pumps) and the "HA" lighting main. At night time the most significant are the canteen, lights and the mechanical plant. The high load in the canteen appeared to be due to large freezers. The night cleaning shift coupled with poor control of lights being left on continuously would contribute to the high lighting load. As a result of the staff practice in overriding the boiler timeclock controls so as to ensure continuous operation, the circulating pumps and the air compressor are also required to operate continuously.

The air compressor supplies compressed air to operate the pneumatic controls. The heater units in each classroom are supplied with hot water from the boiler, but a pneumatic thermostat controls the position of a damper regulating the proportion of fresh (outside) air and recirculated air and a wall mounted switch controls the fan motor. Failure of the compressed air distribution pipes (believed to be due to rodent attack) meant that the thermostat and damper controls did not work although the compressor still ran to drive them. We were informed that maintenance staff had adjusted the dampers to always be fully open to the outside air, thus always heating the cold outside air for delivery to the classroom. The fans are relatively quiet with the switch often mounted in an obscure position, such as on the back wall of the room where it could be hidden by cupboards or pictures. In all cases the indicator light on the fan switch was very dim, and could not be recognised under the high levels of natural light. As part of the work undertaken for this investigation all dampers have been altered to recirculate already warm room air, giving staff and pupils the option of opening the window to adjust the amount of fresh air entering the classroom. The cost of replacing the pneumatic thermostats is to be investigated. The wall switches should be replaced with a simple timer control - to permit the fan to run for only 1 hour at a time. Thus teachers can switch the fans on at the start of the period as required, but the present situation of the fans being able to run continuously could not occur.

c) Wellington Girls College

A walk-through energy audit was undertaken on 13 March 1986. As mentioned previously, Wellington Girls has an identical tower block to that at Wellington College and was therefore intended to be used as comparison. In 1984 Wellington Girls College had total electricity expenditure of $18,500 (ranked 25th) compared with Wellington College's $29,994 (ranked 1st) or $363 per classroom (ranked 27th) compared with Wellington College's $600 per classroom (ranked 2nd).

Figure 34 provides a breakdown of energy use and cost for 1985. Natural gas provided 68% of energy used in the school, but its lower cost meant that it was only 43% of the expenditure on energy. Electricity provided most of the remaining 32% of energy needs -

pumps, lighting and other direct electricity uses including unit heaters - for 57% of the cost. Here again, a small amount of natural gas is used for laboratories.

Figure 35 illustrates the consumption of natural gas and electricity on a per school day basis. The high levels of gas consumption in May, August and September indicate the main boilers are probably operating during the school holidays. Savings of about 200 GJ ($1200) would be expected if turned off. The electricity profile also shows little reduction during those periods.

Figure 36 plots the performance line for oil consumption for a 17 month period based on energy use per weekday as this gave a higher correlation than the performance line based on energy use per school-day. The correlation between energy use and temperature is still low, and suggests the heating controls are not working consistently. Although monitoring of the boilers found them to be operating correctly under timeclock control, the level of correlation is lower for Wellington Girls College than for Wellington College. It is possible that, as discussed for Rongotai College, the school's energy use is related to some other climatic variable other than temperature.

The tower blocks at Wellington Girls and Wellington College are of the same vintage, and oil was the original boiler fuel. However Wellington Girls College had been converted from oil to gas by the fitting of new burners. All other parts of the oil system remained - including the oil burners and the oil tanks. The caretaker reported that the oil tank was still full of oil. The small storage tank in the boiler room indicated that 1100 litres remained in the tank. It was suggested that this oil be removed, and M.W.D. provided the names of suitable companies to C.R.O. staff.

Given the type and significance of the heating system problems found at the other two Wellington schools, it was decided to limit work on Wellington Girls College to datalogger monitoring of the boiler switching, to ensure at least one (comparatively) normal school was monitored. Analysis showed the boilers to be operating under timeclock control, switching on at 6:30 am and off at 3:00pm.

WELLINGTON GIRLS ENERGY USE

Energy Research Group Data

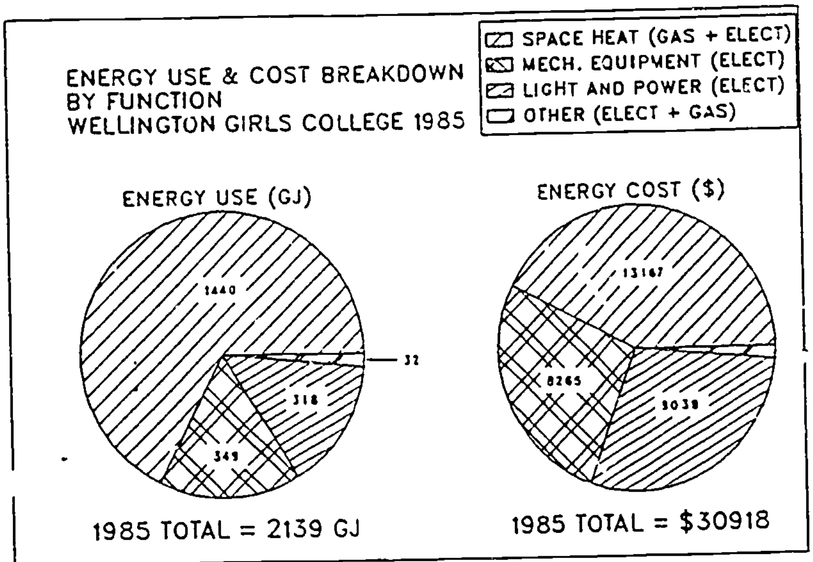


Figure 34

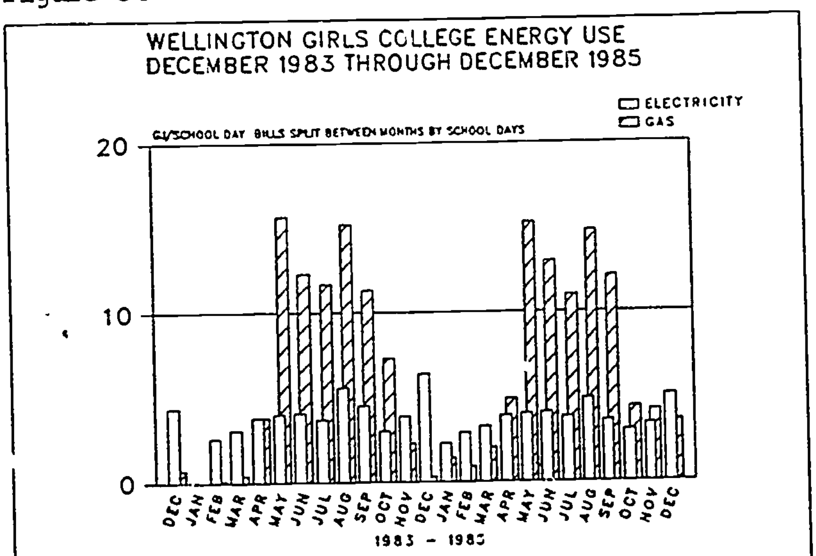
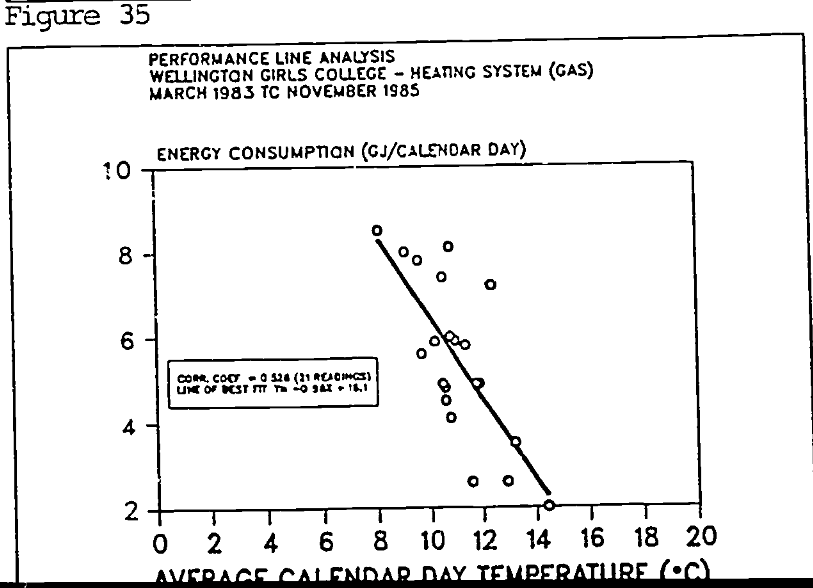


Figure 35



4.1.6 Discussion

Wellington offered a test bed for the use of an energy database for the selection of schools for detailed investigation. In both the schools selected due to high energy use rankings, large energy savings were identified, and action put in place for the savings to be achieved. This work has demonstrated that it is possible for a central selection method to be used for the identification of schools suitable for more detailed investigation, and this in turn reduces the number of schools where intensive investigation is required.

The detailed investigations also benefitted from the depth of information held in the database. The identification of patterns from the energy bills permitted key potential problem areas to be identified prior to site inspection.

Considerable refinement of the selection methods are possible, and a number of recommendations for further investigations in a full Schools Energy Database have been made.

The unfortunate case of the continuous operation of the boiler at Rongotai College offers a unique opportunity for the investigation of the effect of climate on school energy use uninfluenced by normal operational constraints. Additional effort should be invested into a full examination of the data, and comparison with datalogging records from the other two Wellington schools.

Recommendation : The datalogger record for Rongotai College is a unique case of a school being heated for a four month continuous period. N.Z.M.S. climate data should be purchased for that period, and statistical comparisons made with all datalogger records to determine the importance of wind versus exterior temperature in the heating of schools.

4.2 Christchurch Secondary Schools

The city of Christchurch was selected to examine the effects of optimisers on energy consumption. It was intended that by selecting a reasonable number of schools in a city with similar climate across its area, individual site variations would be of less importance to the final analysis. The major part of the improvement to the boiler controls was to be the installation of optimisers to minimise the boiler run time while maintaining comfortable room temperatures for pupils and staff.

Cost savings were not necessarily expected, as it was possible that by providing greater boiler control, improved comfort levels could be obtained at the cost of higher (or more expensive) energy use.

Replacement of the conventional electro-mechanical timeclock control by a microprocessor based optimiser would not alter any existing problems with the heating system unless related to this control. It was expected that staff and pupil complaints would require careful handling to ensure that the benefits from improved boiler control were not lost under a welter of complaints due to other causes.

4.2.1 Hypothesis:

Primary: An optimiser will lead to the boilers running for less hours than either timeclock or manual control while maintaining comfort levels; giving cost (and energy) savings.

Secondary: That both "optimum start" and "optimum stop" controls are necessary for cost (and energy) savings.

4.2.2 Description of Boiler Controls

(1) Permission to run: the primary heating control device gives "permission" to the boilers to run, or not to run. This can be a simple timeclock (START at a fixed time, STOP at a prefixed time) or a modified timeclock (adjusting START and/or STOP times depending on other factors e.g. weather, occupancy, sunlight etc).
An optimiser monitors internal and external temperature(s) and compares them with a user established occupancy requirement (e.g. 9am to 5 pm). The optimiser may determine the latest possible time to start the boilers, yet still ensure that the building is warm at the start of occupancy (optimum START). It may then switch the boilers off if it has calculated that the rooms will remain warm enough for the remaining occupancy time (optimum STOP).

(2) Boiler water temperature control: often the only other heating control, the "on/off' or "cycling control" monitors the return temperature of the water to the boiler. If it drops too low relative to the outward flow temperature, more fuel is supplied to the boiler to increase the flow temperature by switching on a stoker drive or opening a supply valve.

(3) Mixer control: in more sophisticated systems, a "compensator" monitors the return water temperature and references it to the outside air temperature. Based on factors established by the manufacturer and the initial set-up, the compensator

calculates the required water flow temperature to the buildings. It then adjusts the proportions of hot water from the boiler and return flow through a mixing valve to achieve this temperature.

In addition the boiler has a "hi-limit" safety thermostat monitoring the boiler water temperature. If the water temperature is too high, it shuts the boiler down and requires manual resetting before operations recommence.

Various combinations of the heating controls are available e.g. a compensator with an optimum start unit; an optimum stop/start unit; etc. Compared with an uncontrolled boiler system (and assuming correct operation) heating controls reduce energy use and costs. Commonly school boiler systems are fitted with return water temperature control, and in some cases with compensators. In a few modern boiler installations, optimisers have been fitted.

4.2.3 School Selection

Table 14 lists schools in or near to Christchurch city and their heating fuel. The rankings refer to that fuel in the Christchurch city district in the Southern Regional Office schools.

Table 14: S.R.O. SCHOOLS NEAR CHRISTCHURCH BY 1984 FUEL EXPENDITURE

	Individual Fuel			Per Classroom		LHW Total
School	Type	$	Fuel Rank	$	Rank	Rank
Hagley High School	Oil	31900	1	650	1	1
Linwood High School	Oil	18814	2	258	2	5
Burnside High School	Coal	18750	1	198	13	4
Mairehau High School	Coal	11988	4	240	8	15
Papanui High School	Coal	11276	5	168	15	9
Kaiapoi High School	Coal	10340	6	272	5	13
Hillmorton High School	Coal	8383	11	155	18	14
Cashmere High School	Coal	9560	8	157	17	16

Source : Department of Education data

The initial intention of the project was to install and monitor optimisers in 6 Christchurch schools, based on detailed discussions with M.W.D. Head Office, M.W.D. Wellington District Office, and two equipment suppliers - Honeywell and G.E.C.. Following the inspection of 8 schools on the 17 & 18 March, arranged by M.W.D. Christchurch, it became apparent that only 5 schools were suitable for the installation and commissioning prior to the 1986 winter.

The other three schools were rejected largely on the grounds of the types of heating problems already being experienced at the school. In one school the control switch box had been fitted with a soap dispenser and was used for storing tools. It was not felt that the caretaker would be able to offer assistance to the satisfactory operation of the investigation. This example again highlighted the lack of training given to caretakers in the use, care and dangers of boilers and their control systems. In the other school the caretaker had taken part in an optimiser investigation in the early 1980's and was not happy about the problems experienced then. In addition the school had had a new control panel fitted, and the caretaker was getting used to its operation.

Cost estimates were requested from two suppliers for turn-key systems for the five schools. During this process another school, Hagley High, was removed from contention as it was considered that the current heating system was not operating satisfactorily, and there was some discussion over the possible life of the existing building and heating system.

After the quotes had been obtained it was decided that due to the high cost of wiring the interior sensor and the requirement for M.W.D. to charge for all services, to install optimisers in only two schools (Cashmere High School and Hillmorton High School). The other schools, including Hagley High School, were fitted with runhour meters (see Section 4.4). In addition Linwood High School, with an existing optimum-start controller, was monitored. After the installation of these two optimisers it was decided that as it was already well into the heating season, there were no benefits from proceeding with another school. In all, three different optimum controllers were investigated in Christchurch.

4.2.4 Experiment Statement:

(1) Primary: Monitoring the optimiser START/STOP times will provide a comparison with the previous control method - normally timeclocks with caretaker assistance.
(2) Secondary: Monitoring the external temperatures and the optimiser switching pattern will indicate the relative importance of optimum start and optimum stop.

4.2.5 Results

Approval for the installation of optimisers in five Christchurch schools was submitted to the Department of Education on 7 March 1986. Site visits were made on 17 and 18 March 1986. Department of Education letter of approval for the expenditure was dated 25 March 1986. Financial authority to proceed was received by the Ministry of Works and Development, Christchurch on 6 June 1986. The optimisers were commissioned, as shown in Table 9 (at the start of this Chapter) in mid-July 1986. It can thus be seen that there was a three and a half month lag between formal financial approval for the installation of the optimisers and their commissioning. This indicates that energy management cannot be implemented quickly, and careful planning will be required in the development of a full energy management programme for the Department of Education.

a) Hillmorton High School

A Satchwell SMT optimiser was installed in this school.

During the original visit to this school on 18 March 1986, it was noted that the switchboard was very old, with the compensator being a type that was no longer even serviced by the manufacturer. While staff from M.W.D. Mechanical and Electrical Engineering Directorate were visiting the school with the equipment supplier, it was noted that a new switch board was being installed under supervision of P.M.G.. Arrangements were made for the time clock to be replaced with an optimiser, which was then used as a simple time clock until the necessary temperature sensors could be installed.

The boiler house is 16 metres away from the main school building housing the hall, staff offices and staff room. It was decided to locate the interior temperature sensor in a classroom in another block 30 metres away from the far side of the main building. The two options to connect to this sensor were to use the underground piping ducts or overhead cables. Access to the ducts was difficult, involving lifting the concrete duct covers, and likely to be expensive as duct covers tend to be broken by the lifting process. Thus two overhead catenary wires were used to link the optimiser with the classroom sensor. Such an approach is considered to be temporary, and funds have been allocated for their eventual removal. In total 160 metres of sensor cable were required to connect from the classroom to the optimiser in the boiler house.

The optimiser worked satisfactorily once it had been commissioned but it became obvious that all was not well with the boiler system. Additional effort was required from M.W.D. M & E to ensure boilers and pumps worked correctly.

Figure 37 compares daily coal consumption and Degree Days for the "pre-optimiser" and "post-optimiser" periods. Daily coal consumption is calculated under the assumptions given in Section 3.1.3, and the Degree Days from datalogger records of the Exterior temperatures at Kaiapoi High School. The exterior temperature was monitored 8 times per hour, and each reading below 15.6 degrees Celsius was subtracted from 15.6, summed over the day, and then divided by 192 to give the average Degree Days for that day. the daily Degree Days are then summed into the same day groups as the coal delivery. Thus the more degree days shown in Figure 37, the colder the period over which the coal was used.

Linear correlation finds little relationship between the Degree Days and daily coal consumption. Further investigation should be undertaken into this relationship, as discussed for Rongotai College (Section 4.1.6 (a)).

Table 15 illustrates more clearly the effect of the optimiser. The switching information was extracted from the data logger records. Eight readings are taken per hour and thus Table 15 is a summary of 5,568 readings on each of two switches (boiler permission to run and pumps running). The optimiser was commissioned on 12 July 1986.

With the boiler under timeclock control the boilers started at 5 am, and finished at 3 pm. On particularly warm days, the caretaker turned the boilers off earlier, and could also turn the boilers on earlier for particularly cold days.

With the optimiser installed, the boilers started, on average, 40 minutes **earlier** but also finished 3 hours **earlier**. Thus, over the ten school day period from 16 July to 29 July boiler running time savings totalled 23 hours 30 minutes.

Based on coal costs for the month, the boilers cost $13 per school-day runhour. This includes allowance for overnight and weekend stoking. Savings are thus $30 per day. If these savings are maintained for the entire winter heating season, savings of the order of $3200 could be expected. This compares to the 1986 coal expenditure of $8223, and would give savings of 39%.

E?FECT OF SELF-ADAPTIVE C?TIMISER ON ENERGY USE

Based on Analysis of Coal Bills

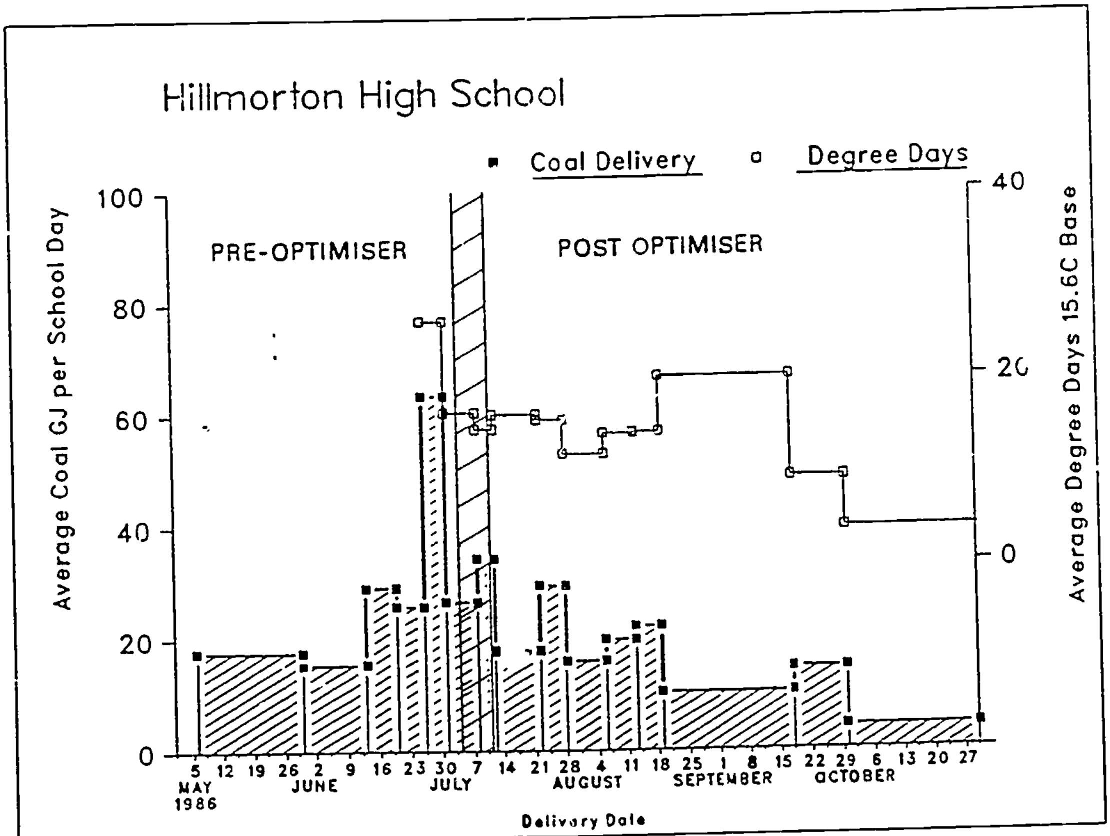


Figure 37

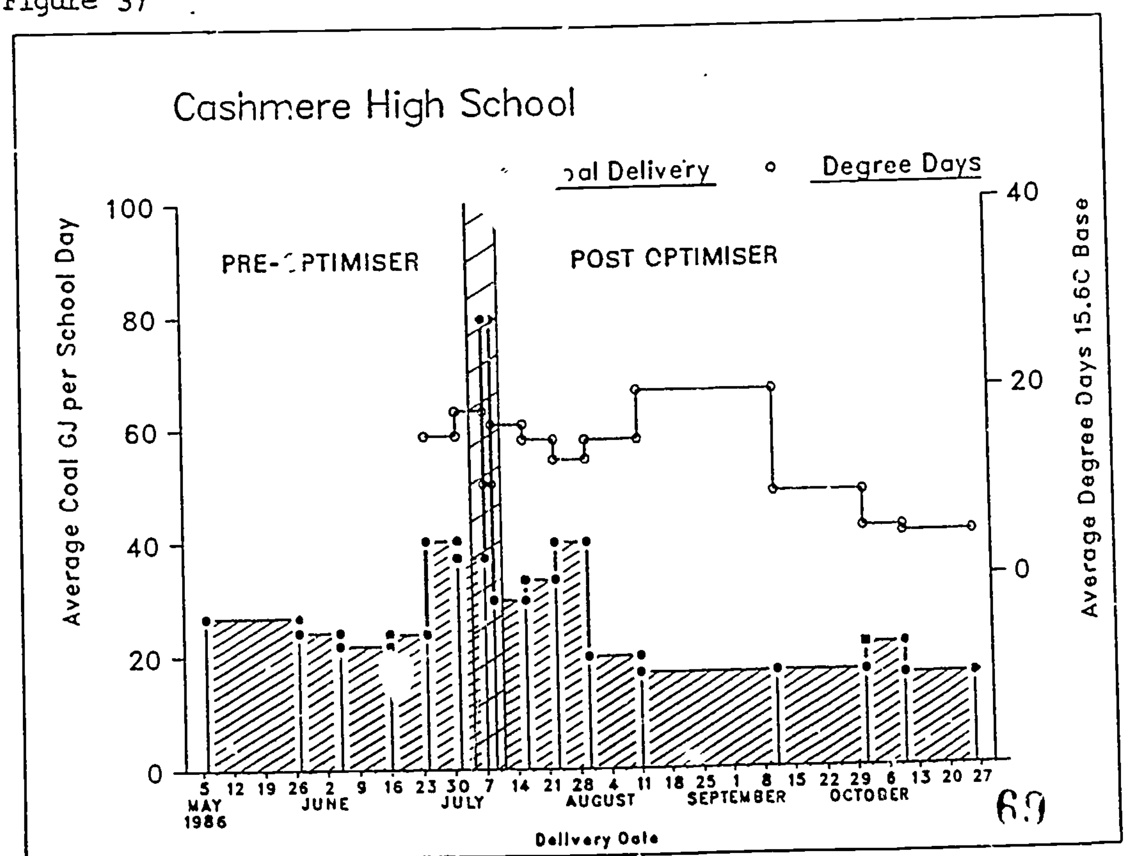


Table 15:
HILLMORTON HIGH SCHOOL - EFFECT OF OPTIMISER ON BOILER RUNNING

JULY 1986

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1 AM START 5:03 STOP 15:03 PM START 18:03 STOP 20:03	2 AM START 5:03 STOP 13:41 PM START 14:11 STOP 15:03 PM START 18:03 STOP 20:03	3 AM START 5:03 STOP 15:03 PM START 18:03 STOP 20:03	4 AM START 5:03 STOP 15:03	5 AM START 9:41 STOP 9:56
6 PM START 17:48 STOP 21:03	7 AM START 5:03 STOP 14:11 PM START 14:26 STOP 15:03 PM START 18:03 STOP 20:03	8 AM START 5:03 STOP 15:03 PM START 18:03 STOP 20:03	9 PM START 18:00 STOP 20:00	10 AM START 5:00 STOP 12:07 PM START 14:00 + STOP 14:45 PM START 15:37 STOP 16:00	11 AM START 6:22 STOP 13:45	12
13	14 AM START 7:52 STOP 8:07	15	16 AM START 0:07 STOP 12:22 PM START 18:07 STOP 20:07	17 AM START 4:45 STOP 12:07 PM START 18:07 STOP 20:07	18 AM START 4:22 STOP 11:37 PM START 12:37 STOP 13:00	19
20	21 AM START 2:07 STOP 13:45 PM START 18:00 STOP 20:00	22 AM START 5:45 STOP 12:15 PM START 18:07 STOP 20:07	23 AM START 4:37 STOP 11:52 PM START 18:07 STOP 20:07	24 AM START 4:30 STOP 11:22 PM START 18:00 STOP 20:00	25 AM START 8:15 STOP 11:37	26
27	28 AM START 3:00 STOP 12:22	29 AM START 6:37 STOP 11:07	30 Logger failed	31 Logger failed		

Notes:

Prior to the installation of optimiser:

Eight school days from 1 July to 10 July 1986.
Boilers start 5:03 am, boilers finish 15:03 pm under timeclock control.

Optimiser Installed:

Three school days from 11 July to 15 July 1986.
Optimiser adapting to heating system, buildings and climate.

After the installation of optimiser:

Ten school days from 16 July to 29 July 1986.
Boilers start and stop depends on climate.
START on average 40 minutes earlier - increase running time by 6 hour 40 minutes
STOP on average 3 hours earlier - decrease running time by 30 hours
Total savings 2 hours 20 minutes a day: or, over the ten days, of 23 hour 30 minutes boiler running time.

U.K. school experience is that "optimum start" is of greater benefit than "optimum stop" (Ref 5). This result demonstrates that the reverse is true under New Zealand climate and proves the secondary hypothesis to be incorrect.
Table 16 compares pre-optimiser and post-optimiser coal use Making no allowance for climate it can be seen that the average coal use per day reduces from 29 GJ per day pre-optimiser to 19 GJ/day post-optimiser, a drop of 40%. This would appear to be of the same order of magnitude as the reduction calculated from examination of the changed switching patterns in Table 15.

Table 16: HILLMORTON HIGH SCHOOL - OPTIMISER SUMMARY STATISTICS

	Pre-Optimiser	Post-Optimiser	Overall
Number of School days	44	62	106
Number of coal deliveries	8	7	15
Total coal (GJ).	1034	750	1784
Average coal per day (GJ/day)	29	19	24

Source: E.R.G. monitoring and analysis of bills.
Note : Averages exclude last delivery.

The installed cost of the optimiser was $5300, giving a 1.66 year payback assuming savings of 40%. The calculation of the potential benefits from an optimiser in this school is robust despite the assumptions that must be made. Even if over a full heating season the savings prove to be half of those calculated, the payback period is 3.3 years and is still an acceptable rate of return.

b) Cashmere High School

The original project design limited the types of optimisers used to those which had demonstrated use under New Zealand condition. It was felt this would ensure that schools would not be used as test grounds for the equipment, considering the likely other difficulties expected. Therefore it was intended to install a Honeywell W989A optimiser in this school, a model already well used in New Zealand. E.R.G. was informed by the suppliers that these units had been superseded, so the newly introduced Honeywell W7032A "Omnitrol" was installed in the school. M.W.D. Christchurch had earlier pointed out that although the Omnitrol was new and untried in New Zealand, it was approximately half the purchase cost of the older equipment. The Omnitrol also had facilities for temperature compensation to replace the school's existing compensator.

Cashmere High School buildings are connected by covered walkways, and thus appeared to offer a simple path between the boiler house and classroom temperature sensor. The reality was not as comforting. Although it was not difficult to place a cable from the boiler house into the cover roof of the walkway, considerable time was spent in pulling the cable through the walkways. Where the walkway met with the school building, a hole for cable access had to be drilled through a reinforced concrete wall. Second and third holes were required to permit the cabl [illegible] travel though a stairwell, and a fourth hole, again through [illegible] nforced concrete wall, to permit the cable to enter the classr[illegible] the sensor. These problems added considerably to the installatio[illegible]rk.

Interior sensors must be located in rooms that are representative both of the climate (notably direct sunshine) and the heating system. Cashmere High School had different heating systems and controls in the two rooms selected for monitoring the interior temperatures - one room with radiant ceiling panels and the other room with fan heaters under teacher control. The teacher would turn off the fan heaters when the room got hot in the afternoon but not turn them on again at the end of the day to permit the optimiser control to be established the following morning. This was resolved by removing the teacher's ability to control the fan. In addition it was found that air blocks meant the radiant panels were not initially working at all and that one fan heater did not work correctly. It was thus necessary for repair work to be carried out on the heaters before the optimiser would have a correct, representative interior temperature to operate satisfactorily.

For the correct operation of any boiler control, exterior temperature sensors must be positioned well away from any extraneous heat source. Prior to the installation of the optimiser, the boiler compensator exterior temperature sensor was positioned directly above the boiler house ventilation fan. When the fan ran, hot air from the boiler house controlled the compensator control rather than the exterior temperature . This was corrected with the installation of the optimiser's new exterior temperature sensor.

In addition to the classroom heater problems, there were optimiser setup problems. These were only of brief duration, and by the end of the heating season the system was working satisfactorily.
Of particular note are:

- the caretaker's use of the Omnitrol controls to over-ride the optimiser controller to achieve his requirements.
- the failure of Omnitrol soon after installation, and its replacement (by the supplier) along with improved power line filtering.
- a delivery of poor quality coal clogged the boilers over one weekend, and school start was delayed by several hours to permit the boilers to be cleared and heat supplied to the school.

Figure 38 compares daily coal consumption and Degree Days for the "pre-optimiser" and "post-optimiser" periods for Cashmere High School. As for Hillmorton High School (Figure 37) there is no strong relationship between daily coal consumption and Degree Days.

Due to datalogger failure prior to the installation of the optimiser, it is not possible to directly compare pre- and post-optimiser switching times.

Table 17 compares pre-optimiser and post-optimiser coal use. It can be seen that the average coal use per day reduces from 30 GJ/day pre-optimiser to 21 GJ/day post-optimiser, a drop of 30%. This is of the same order of magnitude as the reductions calculated for the optimiser in Hillmorton High School.

The optimiser cost $2,500 installed. For the full heating season, 30% savings from the 1986 expenditure on coal of $14,328 would be $4,300 giving a simple payback period of one half of the heating season.

Table 17: CASHMERE HIGH SCHOOL - OPTIMISER SUMMARY STATISTICS

	Pre-Optimiser	Post-Optimiser	Overall
Number of School days	40	62	102
Number of coal deliveries	8	7	15
Total coal (GJ)	1219	1291	2510
Average coal per day (GJ/day)	30	21	25

Source: E.R.G. monitoring and analysis of bills.
Note : Average excludes last delivery, and one day when optimiser control failed.

c) Linwood High School

In 1985 the school's boilers were converted from oil to coal. The existing ROBIN HOOD MAJOR boilers were retained, a coal bunker built onto the boiler house and stokers fitted to supply the coal to the boilers. A complete new control panel was fitted, including a STAEFA timeclock (SCS EUJ2) and optimium controller (RE03). Unlike the optimisers fitted to Hillmorton and Casnmere High Schools, the RE03 is not self-adaptive, and is only optimum start. Thus the optimiser bases its START time on the exterior temperature, but is unable to deal with very cold or very warm conditions. The STOP time is under timeclock control.

Inspection of the boiler house found a mimic control panel, but no written instruction for the use of the controls, or even the optimiser. We were informed that all the M.W.D. staff who had worked on the project had left. The school had experienced considerable difficulties with the conversion, and as part of this project these problems were investigated. The main complaints were about the ash deposited on cars by the chimney, the boiler's early starting time and the lack of heating in parts of the school. The M.W.D. considered that the ash problems had been resolved through correct operation of the boiler. The early start time was traced to the optimiser control sequence. The lack of heat in parts of the school were traced to incorrect pump operation. It was found that the installation had not been fully commissioned, and errors remained uncorrected. These were corrected.

This school also provides examples of the types of problems to be found when the heating system is changed. The school caretaker had been used to dealing with oil - a fuel requiring little manual work, but regular boiler cleaning. Coal however requires the caretaker to ensure the stoker feeds are operating satisfactorily and daily cleaning of ash. As the boiler house was designed for oil, only 2.8 metres were provided for the burners behind the boilers. Into this space the very much larger coal stokers were fitted. The boilers are 3.5 metres long. Thus a 3.5 metre long cleaning rod had to be used, but only 2.8 meters of space were available (much of which was filled with the stokers). To solve this problem a screw-together rod was provided to the caretaker, increasing considerably the amount of work he was required to do to clean the boilers.

4.2.6 Discussion

Savings of the order of 40% were demonstrated for both schools fitted with self-adaptive optimum start/optimum stop optimisers. In the one school were pre-optimiser and post-optimiser logging was carried out it was found that the optimum stop was of greater importance than the optimum start. Further monitoring work should be carried out to confirm this result.

Optimisers monitor both exterior and interior temperatures in order to minimise boiler energy use. Although exterior temperature monitoring can be readily achieved by mounting a sensor outside the boiler house, the interior temperature proved to be more difficult. New Zealand schools tend to be spread out over a large site (often several hectares in area), with the boiler located well away from the main blocks. The cabling caused major difficulties - Hillmorton High requiring 160 metres of cable including two aerial catenaries and Cashmere High requiring 70 metres strung through a covered walkway. In both cases the cost of installation exceeded the cost of the optimiser controller.

Recommendation : **Improved boiler controls, such as optimisers, should be considered for installation when replacement or upgrading work is considered for the boiler control panels.**

It was our experience that adding a more sophisticated control to a heating system highlighted previous maintenance failures which required correction before the system could even start to begin to optimise the boiler operation. In the words of M.W.D. M. & E. Christchurch report (see Appendix II):
'At a very early stage in the project it seemed to the writer that the "cart was before the horse", that is improved boiler controls were being fitted to gauge cost effectiveness when the existing plant was not functioning efficiently.'
It is apparent that heating system, like many other system, are maintained to the level required by the most flexible component. In this case the extremely resilient caretaker was being replaced by an electronic controller, and it is to be expected that additional maintenance is required.

Recommendation : When improved boiler controls are installed on an existing school heating system, full inspection and corrective action is to be undertaken prior to final commissioning.

New schools, or the complete rebuilding of old boiler houses should not have such problems. The data collected by this project would suggest that there are cost savings to be made through the use of optimisers in new schools.

Recommendation : Self-adaptive optimisers should be installed in new schools.

The spread out nature of New Zealand schools also can cause control problems where an optimiser operates optimally for just one of several different heating zones, but no detailed investigative work has been undertaken. Problems to be considered include the placement of interior and exterior temperature sensors and the abilities of different optimisers to deal with the different zones.

Recommendation : Further investigations should be undertaken into problems of different heating zones under one optimiser control.

Caretaker training is an essential part of any boiler controls. Optimisers, which by their nature are more complex than conventional timeclocks, require more operator training.

Recommendation : Caretakers must receive full training with any new equipment that is to be under their care. Ongoing programmes of support and training are also required.

It should not be forgotten that electronic optimisers with the ability to store different programmes for different days require reprogramming at the start of each heating season.

Recommendation : It must be recognised that modern control equipment requires ongoing support and maintenance. In the case of optimisers this includes reprogramming each year for the coming heating season. Other controls require regular checking and calibration. Funds must be available for this purpose.

4.3 Wellington Primary Schools

As shown in Section 2.2, although Primary Schools in total spend as much on energy as Secondary Schools, the larger number of schools means that the per school consumption is far smaller. In fulfilment of the objectives of the Department of Education this project concentrated effort on schools likely to provide the greatest benefits from improved energy management - namely secondary schools.

However primary schools were not ignored. Extensive discussions were held with the Wellington Education Board, and a number of schools inspected.

4.3.1 Hypothesis:

Primary: That walk-through energy audits will identify opportunities for improved energy management.

4.3.2 School Selection

As described in Section 3.1 accounts information was obtained from the Wellington Education Board for all the schools under its care; loaded into computer database; checked; and analysed. After discussions with W.E.B. four pairs of physically similar schools in nearby locations were selected. The energy accounts data for these schools were double checked with the suppliers to ensure that all bills were accurately recorded.

A set of files has also been prepared - one for each W.E.B. school.

Accompanied by W.E.B. staff one pair of schools was inspected by E.R.G. staff. Following that visit, three more primary schools were inspected.

4.3.3 Experiment Statement

(1) Primary: Use the expenditure database to select schools for inspection and undertake a brief walk-through energy audit.

4.3.4 Results

Table 18 provides information on the schools inspected. Note that the total amounts under consideration are considerably below those give in Table 10 for Wellington Secondary Schools. The Per Classroom expenditure for Khandallah and Tawa Primary Schools is high compared to the secondary schools.

Table 18: WELLINGTON PRIMARY SCHOOLS INSPECTED

	SCHOOL				
	Oxford Crescent	Fraser Crescent	Khandallah	Tawa	Evans Bay
Total energy (GJ)	529	213	590	527	639
Total energy ($)	4160	1843	9649	7135	8669
Energy per classroom (GJ)	31.1	13.3	42.1	40.5	35.5
Energy per classroom ($)	245	115	688	549	482
Number of classrooms	17	16	14	13	18
Fuel	Coal	Gas	Gas	Gas	Gas

Note : Data relates to 1984 calendar year.
Source: W.E.B. data

a) Oxford Crescent Primary and Fraser Crescent Primary
These two schools in Upper Hutt were both built in the 1950's, and are of similar size. Oxford Crescent Primary spent 126% more on energy than Fraser Crescent Primary for 148% more delivered energy. On a per classroom basis, Oxford Crescent Primary used 134% more energy per classroom than Fraser Crescent at 113% more cost.

Oxford Crescent Primary is heated by a coal fired cast iron sectional BRITANNIA boiler. The school is divided into three heating zones:

(1) Standards Wing
(2) Infant Wing
(3) Cloak rooms, staff room, administration area, dental clinic.

In addition two demountable prefabs are used - one double classroom and one single classroom. They are heated by coal burning pot belly stoves. The hall is electrically heated. The main school boiler is under timeclock control, turning on 6 am and off at 11am. The timeclock time and day of week was correctly set. The caretaker starts the fires in the prefab buildings at 7 am.

Fraser Crescent Primary is heated by a gas fired cast iron sectional NUWAY MODEL 004 boiler which had been converted from oil to gas "some years ago". The dental clinic and hall are electrically heated. The main boiler is under timeclock control turning on at 6.40 am and off at 10.30 am. The timeclock time and day of week was correctly set.

The two schools electricity expenditures are comparable (Oxford Crescent Primary $647, Fraser Crescent Primary $656) with the heating fuel cost (Oxford Crescent Primary $3513, Fraser Crescent Primary $1187) accounting for the discrepancy. The per unit heating fuel costs appeared average for the area - coal at $160 per tonne, gas at $7.10 per GJ.

One possible explanation is that Fraser Crescent is on the same site as Maidstone Intermediate School. The two schools are fed through one gas meter, and the bills proportioned between the two. It is possible that Fraser Crescent is paying less than its equitable share. Energy costs in both schools are paid through the W.E.B. so the total bill is met from the same source.

b) Khandallah Primary School
The school is located on a steep, exposed site. The gas fired CRANE AND WHITEHALL NO 3-7 sectional boilers are located in a boiler room attached to the Administration Block (includes library and hall) and provide heated water to pressed steel radiators in a two storey Intermediate Block, and a single storey Senior Block. A single storey Junior Block (part of the original school on the site) is heated with unit gas heaters, as is the two class room temporary block. The timeclock was disconnected and the boilers under manual time control. A new CXC compensator controller and pump had been fitted to Boiler 1 at the start of winter.

Table 18 shows that the per classroom energy expenditure is high for this school, and this may be due to the exposed nature of the site. As usual the classrooms are supplied with natural light through large areas of glass, and numerous opening windows permit the entry of the Wellington zephyr.

c) Tawa Primary School

The school consisted of seven buildings on a large flat site. The gas fired GENERAL GAS CHIEF package boiler in the main block boiler room heated the three classrooms in that block, and the classrooms in a separate block. There was a strong smell of leaking gas in the main boiler room. The Hall is electrically heated with wall mounted radiant bar heaters. The boiler in the second boiler room, a NO 2-6 sectional gas fired boiler, heated the three classroom in that block and the classrooms in the remaining permanent block. A relocatable temporary classroom was heated with wall mounted radiant bar heaters. Both boilers were under timeclock control, although neither time was set accurately.

d) Evans Bay Intermediate School

The school consists of two main blocks, both two storeys high, facing each other across a surfaced playing area. Two relocatable blocks are also in use. The main blocks are supplied with heated water through underground pipes from a gas boiler, while the temporary buildings have unit electric heaters.

The school sits on an extremely exposed site, close to Rongotai College. The main block is notable for its large areas of north and south facing glass. Each classroom has windows opening on both sides, permitting the gentle Wellington wind to penetrate the deepest corners.

4.3.5 Discussion

The overall impression obtained from these five walk-through audit inspections was that these primary schools were better maintained than secondary schools. The primary schools were very much smaller than the secondary schools, and as a consequence the heating system less complex. Their total energy bills were as much as an order of magnitude smaller than the secondary schools, although the per classroom ratios could be high.

The caretakers all lived on or near to the school site, and appeared to regard the school as part of their family. This could be due to the smaller physical size of the schools. All these schools had large playground areas.

It was interesting to note that the two schools on exposed sites (Evans Bay Intermediate and Khandallah Primary) both had high energy expenditures. However no design attempt appeared to have been made to limit the worst excesses of the weather - notably the problems caused by large air movement through the numerous opening windows on both sides of the classroom. Further investigations are required of energy management on exposed sites. Analysis of datalogger records as recommended in Section 4.1.6 (a) will be of significance to primary schools as well as secondary schools.

Immediate opportunities for improved energy management were not identified by these walk-through energy audits. In total, primary school expenditure on Light, Heat & Water is as great as secondary schools, and further investigations should be undertaken into primary schools.

Recommendation : Further investigations be undertaken into opportunities for improved energy management in primary schools.

4.4 Runhour Meters

The analysis of energy expenditure information is a complex activity. Not only are different schools subject to different energy tariffs, they use different fuels and have different types of heating systems.

Runhour meters can best be compared to the speedometer in a car. As long as the car is moving, the meter turns and records the distance travelled. For a runhour meter, as long as power is supplied to the boiler burner, the meter turns and records the elapsed time. Runhour meters offer benefits for long term monitoring. They are low cost (of the order $50 installed), easily read and reliable.

4.4.1 Hypothesis:

Primary: Runhour meters provide a simple, low cost method for monitoring the health of a heating system.

Secondary: Runhour meters will assist in the diagnosis of heating system problems

4.4.2 Use and types of Runhour Meters

When hot water (or steam) boilers are used for school heating, monitoring of the actual operation of the plant will give a very good indication of actual performance. The installation of complex and expensive monitoring equipment can not be justified on any thing but a short term basis. Such datalogging (whether using an electronic data logger storing in a computer analysable form, or on paper for later human examination) produces enormous amounts of data that require careful and regular examination. Problems can easily be lost in the weight of data and thus for routine plant monitoring a simpler data recording method, such as runhour meters, is required.

Standard runhour meters are cumulative - that is to say the hours continue to increase, and not reset to zero. Thus standard runhour meters must be read twice - once at the start of the period of interest, and once at the end. The difference between the two readings is the amount of time the boiler burner has been running.

Resettable runhour meters can be reset to start from zero whenever required. This means that actual runhours can be read directly, without the need for additional mathematics. The start time must be noted, and care taken not to accidentally reset the unit,and thus lose all the information recorded. For this reason they are normally used in tandem with a standard meter.

4.4.3 School Selection

It was decided to install runhour meters in six of the Christchurch schools described in Section 4.2.3. In the main the schools were considered to be of interest for the installation of optimisers but practical considerations had meant that was not possible.

4.4.4 Experiment Statement

(1) Primary: Install runhour meters in five Christchurch Schools and read regularly over the heating season.
(2) Secondary: Compare runhours with other information collected by the project to determine the existence of patterns.

4.4.5 Runhour Data

Regular readings of runhour meters can be used to supervise the boiler use use and maintenance.

(i) total runhour time for the school's boilers:
If considerably higher than the average, this may indicate problems with the heating system or the boiler controls. If the heating system is failing to deliver heat to the classrooms, an optimiser will run the boilers for longer to meet the required temperature requirements. Manually controlled boilers may have the timeclock control overridden and the boilers left on in an attempt to increase the classroom temperatures.

(ii) Need for maintenance:
In general the maintenance requirements for a boiler are related to the operating hours. Identification of boilers with higher than average runhours can be used to ensure maintenance is suited to the boiler operations in the school.

(iii) Balancing boiler use:
Normally schools have two boilers, of similar size. This ensures that should there be any problems with one boiler, it can be taken out of service for repairs or maintenance while the other continues to meet the heating load, under normal circumstances. If one boiler has considerably longer runhours than the other, there may be a problem with the boiler controls

4.4.6 Results

Five Christchurch schools were instrumented with runhour meters and regular readings taken, and one Wellington school with existing runhour meters was monitored. Readings were made as near as possible to the start of the heating season, and at the end of the season. The results indicate that even the runhours for a heating season can be useful for the identification of heating system problems. The current Head Office accounts provide only the total energy expenditure by fuel type from secondary school annual accounts, and provide nothing for individual primary schools.

Table 19 presents run hour information for 6 schools - 5 in the Christchurch area and one in Wellington. Each school was fitted with a separate runhour meter on each boiler.

Table 19 : SCHOOLS MONITORED WITH RUNHOUR METERS - WINTER 1986

School	Fuel Type	Cost per	Unit	Run-hours	Energy (GJ)	Cost ($)
Cashmere High School	Coal	$127	tonne	751	1599	$ 9527
Hillmorton High School	Coal	$101	tonne	677	1784	$ 8224
Papanui High School	Coal	$114	tonne	1148	2871	$14815
Kaiapoi High School	Coal	$163	tonne	655	1510	$11395
Hagley High School	Oil	$0.38	litre	1043	1959	$18725
Wellington College	Oil	$0.31	litre	948	2193	$17418

Note : Hagley High School costs and energy consumption are available only until the start of the August Holidays.

"Runhours" refer to the number of hours that fuel is being supplied to the boilers (each school in the table having 2 boilers), not the number of hours the heating system is "turned on". Fuel is supplied through control valves that respond in a preset manner to temperature requirements. Schools generally have two boilers, one of which is normally permitted to run, with fuel being supplied to maintain the temperature of the water being circulated to the classrooms. If the temperature falls because more heat is required by the classroom, the second boiler comes into use. It is normal practice to cycle boiler use - with one boiler "leading" one month, and following or "lagging" the next. In older systems this is achieved through manual switching or adjustment of boiler thermostats, more modern electronic controllers including this as part of their control programme. This ensures, on average, both boilers will run for the same length of time.

Figure 39 through Figure 41 provide further analysis of the 1986 heating season.

Figure 39 shows the run hours for each boiler at each school. It appears that Wellington College Boiler 2 is running far more than Boiler 1. This implies that the boiler lead and lag sequence has not been alternated during the year. At the end of the heating season Boiler 1 showed a total of 4764.25 runhours, and Boiler 2 10205.26 runhours. It would thus appear that the sequencing has not been altered for a number of years.

Figure 40 compares runhours per calendar and per school day for the "heating season". It is clear that Wellington College (20.6 runhours per school day) boilers are in almost continuous operation. Hagley High School (15.3 runhours per school day) and Papanui High School (17.1 runhours per school day) also appear to be high.

Additional analysis can be undertaken by matching energy cost and consumption with runhour information. Figure 41 indicates the different costs of fuels - with oil costing approximately $5 per runhour more than coal. Note that Kaiapoi High School's higher coal costs ($163 per tonne compared to $101 to $127 per tonne for the Christchurch city schools) put its cost per runhour up to the level of schools using oil. With the storage and cleaning problems associated with coal, this suggests that the effective cost per runhour (including extra caretaker labour) is higher than for the schools using oil.

4.4.7 Discussion

Runhour information is more useful for the determination of likely heating system problems than total annual energy expenditure, which is all that is currently available. Ongoing monitoring of boiler runhours would assist in the identification of heating system problems, and thus permit limited maintenance funds to be directed to heating systems with the greatest problems. However the results of the limited runhour monitored discussed here are insufficient for full determination of their potential benefits.

It has been proposed that a detailed investigation be undertaking to examine the use of runhour meters in a larger number of schools. The proposed investigation will cover:

(i) the comparative value of data from two types of runhour meters - resettable and non-resettable

(ii) the value of regular reading of the meters

(iii) the analysis of the runhour data, and its potential use in an energy management programme.

Recommendation : **That a pilot project installing and monitoring at least 20 runhour meters be undertaken to determine the likely benefits from such ongoing monitoring.**

RUNHOUR METERS – WINTER 1986

Energy Research Group Data

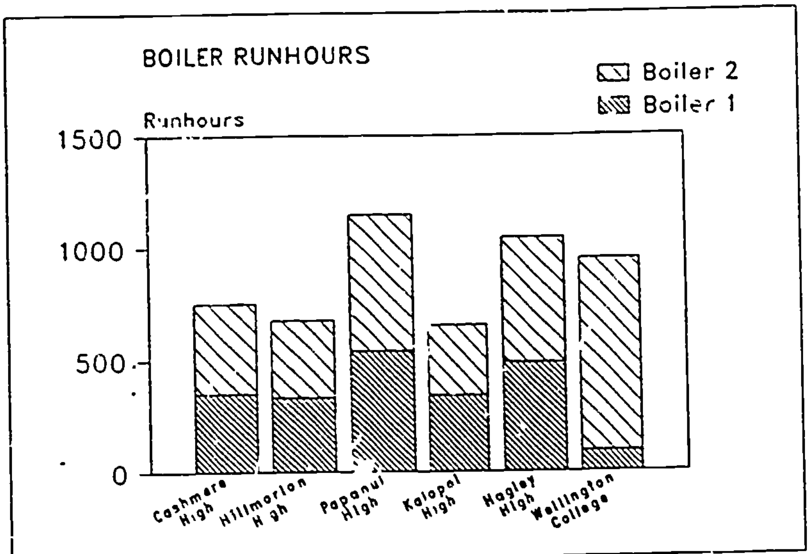


Figure 39

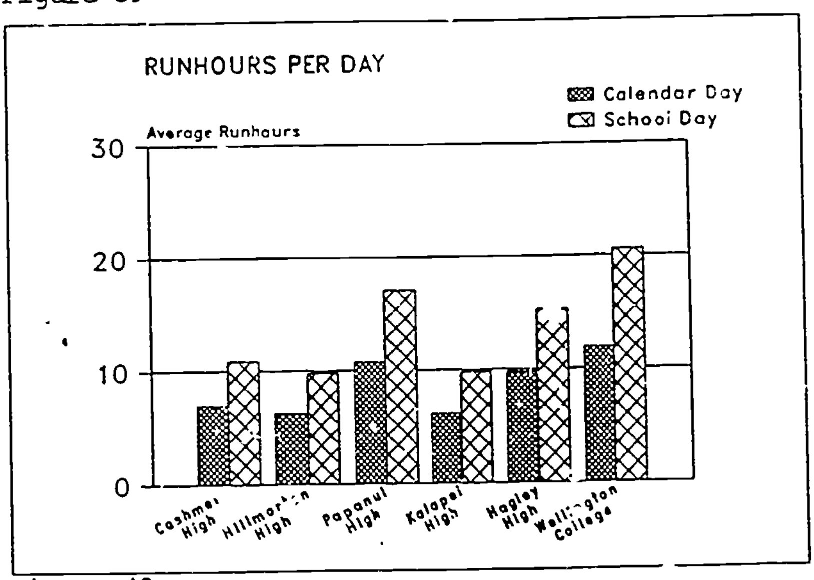
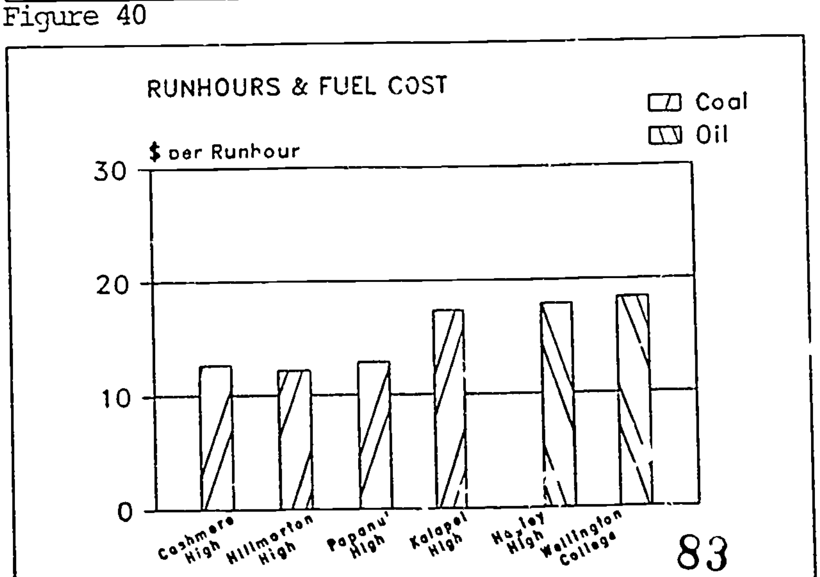


Figure 40



5. CONCLUSIONS

5.1 Action

The investigations described in this report have shown that improved energy management in New Zealand schools has the potential to achieve considerable cost savings. It must be recognised that these savings will only be achieved through increased expenditure, notably on building management and maintenance.

In all cases the savings achieved have resulted in paybacks of less than 2 years, and will assist with the containment of Light, Heat & Water expenditure in coming years. Department of Education expenditure on Light, Heat & Water totalled $18.5 million in 1985/86. The Department's goal should now be to achieve savings through energy management of at least 16% or $3 million in the coming years.

Recommendation : **The work carried out by this project has** demonstrated **that** real savings are **possible through improved** energy **management** based on a database selection **method. A programme of** Energy **Management** can now be implemented **within the** Department of Education.

5.2 The Road to Energy Savings

Typically three approaches towards making energy savings are available (Ref 3):

a) GOOD HOUSEKEEPING - involving little or no capital expenditure, this approach relies on action (and goodwill) of key personnel e.g. Caretaker, Executive Officer, Headmaster, Teachers etc.

b) LOW COST IMPROVEMENTS - improvements that can be carried out in conjunction with routine maintenance work, and should cause little or no disturbances to the running of the school. Examples include improved boiler controls, insulation of pipes, maintenance of radiators etc.

c) CAPITAL INVESTMENT PROGRAMME - often involving large expenditure of funds, these will require careful planning, and may need to be timed to coincide with major improvement and replacement programmes. Examples include replacement of boilers, improved lighting controls, replacement of glazing, building redesign, and even rebuilding.

Although the first approach can result in considerable immediate energy savings, this initial impact will not last without continued support assisting all participants to "do a little more". The latter two approaches, although requiring some additional staff input, do so only in so much - those involved are required to be better at their normal work. Thus the caretaker is required not to take on additional responsibilities, but rather ensure the existing responsibilities are carried out better. The technological potential for energy savings are guaranteed, assuming the technology is correctly installed, commissioned and maintained.

In all cases participants in an effective energy management programme are provided with information to assist them to manage energy better. The feedback loop must be closed.

To summarise the results of the investigations undertaken for this report, as the first step of an ongoing energy management programme it is necessary to bring schools up to a satisfactory level of maintenance ("Low Cost Improvements" and "Capital Investment Programme"). A programme of "Good Housekeeping" can then be implemented to ensure ongoing benefit is maintained.

This report is the first step in an ongoing energy management programme within the Department of Education. The examples considered here have served to confirm savings are possible and the selection techniques are suitable. The next step should be to implement a few of the techniques shown to be beneficial in a larger number of schools to determine the types of difficulties to be experienced when used for ongoing energy management. The third step will involve the inclusion of the largest secondary schools and a number of primary schools into the programme. The fourth step should include all medium size secondary schools, and all the large primary schools. The final step will be to include the remaining schools showing the likelihood of real returns. It is unlikely that there will be acceptable paybacks for improved energy management in all schools, and thus some schools may never be included in the programme.

5.3 Energy and Maintenance Management

It has again been shown that the reason for excessive energy use in schools is that energy is not properly managed. The reasons are clear - firstly a lack of information for those responsible for maintenance, and secondly a lack of any person with responsibility for energy management. There is only a one way flow of energy management information:

(i) the caretaker runs the system day-by-day;
(ii) the school receives the fuel bill and certifies the account;
(iii) the Secondary School Council, the Education Board or the school pays the bill as it has been certified by the school; and finally
(iv) the Department of Education refunds the expenditure as the correct procedures have been followed.

At no stage is the energy consumption itself examined. Neither are comparisons made with consumption norms or even past year's expenditure. Expenditure feedback is not provided to those operating or maintaining the system to assist them with their management.

This is in the main due to that fact that expenditure on Light, Heat and Water is treated as if it were limitless, whereas both Maintenance and Capital expenditure are tightly controlled. Our observations suggest that, as a consequence of this difference in control, energy costs can rise without limit because of a lack of preventative maintenance or investigation.

It has been shown that there is a cost attached to not undertaking maintenance, just as there is one to undertake the work. Under the previous maintenance system, M.W.D. provided budgetary estimates at the start of the financial year. These were then discussed with the relevant regional office and after adjustment submitted through Head Office to become part of the overall Department Budgetary cycle. At any stage of this process the monetary allocations could be reduced, but without any consideration of the physical meaning of this reduction. Thus when the overall budget is reduced a decision is made to defer some maintenance work, but no priority list is available which ranks that work in terms of the consequences of not doing it.

The recommendation has been made (2.2.3) that both options - action and inaction - should be costed to ensure that budget decisions can be soundly based. At present the cost of doing nothing is implicitly considered to be zero. The examples discussed in this report suggest that this cost can be very high. There is a need to link more closely the infinite Light, Heat and Water budget with the limited Maintenance budget.

M.W.D. now charges directly for all services and this should ensure that bills refer to specific work, rather than a total, portmanteau grant request at the start of the year. If the Department of Education establishes a system for managing maintenance in all schools then monitoring and analysis will ensure that limited financial resources can be directed where the need is greatest.

5.4 Incentives

There is also the need to consider the question raised in our original proposal: how is the individual school, Education Board or Secondary School's Council to be encouraged to contribute to the continuing success of an energy management programme?

At the "boiler door", if heating systems are to be used to the standards set by the designer, then as discussed in Section 3.2.1, instructions must be available to those using the system i.e. the caretaker or substitute. There will be a cost associated with this, and in the past this cost has not been met. It is necessary to recognise that energy wasted through incorrect operation has a cost, and providing useable information does have a real payback.

At the school level, some form of incentive must be provided to firstly remove the pressure on caretakers to heat to wasteful levels and secondly to make the whole school interested in ensuring the most efficient operation of the heating system is achieved (see for example Section 4.1.6 (a)). The caretaker cannot be expected to maintain continuous monitoring of the heating system - checking every heater is operating correctly every day. It is necessary to at least involve the staff, and possibly the pupils, in the process of energy management.

We suggest the providing of incentives in the form of a share of the savings is likely to be the most effective form of encouragement, but further investigation is required.

Recommendation : The provision of incentives to schools to encourage their involvement in energy management be investigated. Sharing the savings achieved should be considered as incentives. Methods of measuring the savings are also required.

5.5 Caretakers

In all the work undertaken for this project, school caretakers have been willing, interested assistants. However in very few cases had they received any training in the use and control of the heating system. In most cases they lacked even a brief guide to the system operation, and relied on the control switch labels and "experience".

This contrasts markedly with the case for principals and teachers where: (1985 Baseline Study of State Secondary Schools - Ref 6)

> "Ninety-seven percent of principals had received at least one type of management training."
> "The proportions who had taken at least one type of management training were 94% for deputy principals and 86% for S.M.s".

There is a need for caretakers to receive better training in the maintenance of the school and this recommendation is made in Section 4.2.6. Such training could form part of the overall improvement of the management of maintenance within the Department.

6. FURTHER WORK

The recommendations for further research can be divided into three areas:

(1) Further analysis of datalogger monitoring records obtained during the 1986 heating seasons;
(2) Checking of savings from improved boiler controls installed during the 1986 heating season; and
(3) Further analysis of LHW accounting data to establish the most suitable methods for the selection of schools for detailed energy audit inspections.

6.1 Analysis of Records from Monitoring

A large amount of data was recorded during the 1986 heating season, but limited analysis undertaken. Only limited analysis was carried out on the lack of relationship between heating energy and the outside temperature. This was first discussed in our previous report (Ref 1), and the current study appears to confirm that wind is more important that temperature. Further analysis must be undertaken before any firm conclusions can be drawn, as recommended in Section 4.1.6 (a).

Of particular importance is the datalogger record for Rongotai College which is a unique case of a school being heated for a four month continuous period. This data ought not be wasted as it may have great significance for the future design and operation of school heating systems.

The change in the government policy towards the use of data collected by government agencies means that it is necessary to purchase climate data from the N.Z.M.S. to permit statistical comparisons to be made to determine the importance of wind versus exterior temperature in the heating of schools.

6.2 Calculation of Savings from Improved Boiler Controls

Improved boiler controls were not installed until late in the heating season, and therefore all calculations of potential benefit are based only on limited data. It is suggested that 1987 accounts data be collected for the two Christchurch schools and the Wellington school fitted with self-adaptive optimisers.

In addition further monitoring of Rongotai College is suggested as it is located close to the Energy Research Group. The costs for such monitoring would not be high, but it would provide more information on the benefits of optimum start and optimum stop boiler controls.

6.3 Procedures to Identify Schools With High Energy Expenditures

It has been demonstrated that a "Schools Energy Database" would permit the identification of schools with the highest potential for savings through improved energy management. The full range of indexes which might be used in a routine energy management programme have not been investigated. A number of recommendations have been made to investigate such indexes. Possible indexes include the change in energy use from year to year and variations between schools in similar locations.

A pilot project to further investigate the benefits of runhour meters is recommended. Further investigations are recommended into methods for examining energy use in primary schools. The major constraint for primary schools is the small size of the schools resulting in long paybacks if expensive work is carried out. It is likely that the skills learnt from the larger secondary schools will also be of value in primary schools.

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Appendix I

Database Structure and Sample Printout

Considerable data has been collected by this project, and organised into SAS datasets. Suitable analysis programmes have also been written.

The print out on the following eight pages is an example of the tyope of information record, in this case for Cashmere High School in Christchurch. Basic information, as given in the first page of the printout, is available in this form for most Secondary Schools and most Primary Schools in the Wellington Education Board.

Energy accounts have been obtained for the Secondary Schools listed below, and all Wellington Education Board Primary Schools.

Aranui High School
Burnside High School
Christchurch Boys
Newlands College
Onslow College
Papanui High School
Rongotai College
Timaru Boys
Wellington College
Wellington East
Wellington Girls
Wellington High School

LISTING OF ALL SCHOOLS DATA BY SSPRINT2

DATASETS=SS.NAMES SS.RACCOM

SCHOOL: Cashmere High School ABBREVIATION: Cashmere H Sch CODE-NAME: CASHM

ADDRESS: Rose Street , Christchurch 2 .

SCHOOL-BOARD: Christchurch S S Counc BUILDING-TYPE 5 REGION: S NEAREST-MET.-STATION: 109

No.-OF-CLASSROOMS (1980): 61

BUILDING DATA (DATASET=SS.ACCOM80)

	BLOCKS	CLASS AREA	CLASSROOMS	HEATED AREA	HEATED ROOMS	TOTAL AREA	TOTAL ROOMS
LARGE PERMANENT	7	3799	53	6065	119	8861	219
SMALL PERMANENT	3	367	6	810	9	1202	22
TOTAL PERMANENT	10	4166	59	6875	128	10063	241
TEMPORARY	3	127	3	171	5	206	8
SCHOOL TOTAL	13	4293	62	7046	133	10269	249

LIGHT, HEAT and WATER COSTS FROM RETURNS TO DEPT OF ED (DATASET=SS.LHW1)
CLASS No. FOR 1980 (61) EXCEPT LHW84 WHICH USES 1985 CLASS No (61)

	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
TOTAL	3049	3672	3905	3937	4716	6783	9673	13823	12824	-1	17015	17708	22141	22912	22040
PER CR	49.9	60.2	64.0	64.5	77.3	111.2	158.5	226.6	210.2	-0.0	278.9	290 3	362.97	375.61	361.31

ENERGY USE AND COST OF FUELS (DATASET=SS.FUDATA SS.FCEQ78-84)

YEAR	ENERGY	COAL	ELECT	GAS	OIL	TOTAL
	COST($)	5162.00	5914.50	1513.50	0.00	12590.00
1978	QUANTITY	87.80	173800.00	1349.70	0.00	
	USE(GJ)	2019.00	625.68	134 97	0.00	2779.65
	COST($)	4283.68	8751.55	2439.35	0.00	15474.60
1979	QUANTITY	103.10	193910.00	1728.10	0.00	
	USE(GJ)	2371.00	698.08	172.81	0.00	3241.89
	COST($)	4407.54	9081.55	3085.06	0.00	16574.20
1980	QUANTITY	84.41	178910.00	1656.88	0.00	
	USE(GJ)	1941.00	644.08	165.69	0.00	2750.76
	COST($)	9113.00	12173.00	0.00	0.00	22912.00
1983	QUANTITY	.	.	.	.	
	USE(GJ)	.	.	.	.	.
	COST($)	9566.00	11039.00	534.00	0.00	22040 00
1984	QUANTITY	.	.	.	.	
	USE(GJ)	.	.	.	.	.

LISTING OF ALL SCHOOLS DATA BY SSPRINT2

SCHOOL Cashmere High School

DEGREE DAY DATA (DATASET=SS.NAMES)

COOL15 1222 COOL20 2134 FULL15 1471 FULL20 3053 DOZEAST 4 DOZR20 4

ENERGY USE FROM METERS (DATASET=WN.EUDATA2)

BILLS UNDER $12 ARE NOT CHECKED. ENERGY USE ($/UNIT) IS CHECKED AGAINST MEDIAN FOR THAT FUEL FOR THAT YEAR
FOR CHANGED M=MISSING VALUE L=COST PER UNIT<0 2•25% QUARTILE G=COST PER UNIT>2•75% QUARTILE. A=EX LOTUS.

ACCOUNT-NUMBER METER-NUMBER FUEL C

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
06MAY86 – 27MAY86	.	7.300	A	T	911.00		.	.	.	124.79
27MAY86 – 05JUN86	.	6.590	A	T	752.00		.	.	.	114.11
05JUN86 – 16JUN86	.	6 910	A	T	788.00		.	.	.	114.04
16JUN86 – 24JUN86	.	6.480	A	T	739.00		.	.	.	114.04
24JUN86 – 01JUL86	.	7.300	A	T	833.00		.	.	.	114.11
01JUL86 – 07JUL86	.	6.790	A	T	775 00		.	.	.	114.14
07JUL86 – 09JUL86	.	7.230	A	T	825.00		.	.	.	114.11
09JUL86 – 16JUL86	.	6.760	A	T	771.00		.	.	.	114.05
16JUL86 – 23JUL86	.	7.570	A	T	999 00		.	.	.	131.97
23JUL86 – 30JUL86	.	9.100	A	T	1201.00		.	.	.	131.98
30JUL86 – 11AUG86	.	7.200	A	T	950.00		.	.	.	131.94
11AUG86 – 11SEP86	.	9.890	A	T	1305.00		.	.	.	131.95
11SEP86 – 01OCT86	.	10.720	A	T	1415.00		.	.	.	132.00
01OCT86 – 12OCT86	.	6.880	A	T	998.00		.	.	.	145.06
12OCT86 – 01NOV86	.	7.300	A	T	1059.00		.	.	.	145 07

ACCOUNT-NUMBER 369617 METER-NUMBER FUEL C

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
08OCT81 – 26OCT81	.	11.120	A	T	800.00		.	.	.	71.94
22APR82 – 28MAY82	.	10.190	A	T	774.00		.	.	.	75.96
28MAY82 – 09JUN82	.	10.990	A	T	820.00		.	.	.	74.61
09JUN82 – 24JUN82	.	11.090	A	T	842.00		.	.	.	75.92
24JUN82 – 02JUL82	.	10.470	A	T	816.00		.	.	.	77.94
02JUL82 – 21JUL82	.	10.180	A	T	794.00		.	.	.	78.00
21JUL82 – 30JUL82	.	10.820	A	T	854.00		.	.	.	78.93
30JUL82 – 10AUG82	.	10.760	A	T	839 00		.	.	.	77 97
10AUG82 – 10SEP82	.	9.620	A	T	750.00		.	.	.	77.96
10SEP82 – 19OCT82	.	9.950	A	T	776 00		.	.	.	77.99
19OCT82 – 01NOV82	.	10.570	A	T	824.00		.	.	.	77.96
24FEB83 – 28APR83	.	10.340	A	T	827.00		.	.	.	79.98
28APR83 – 20MAY83	.	9.680	A	T	871.00		.	.	.	89.98
20MAY83 – 02JUN83	.	5.080	A	T	457.00		.	.	.	89.96
02JUN83 – 10JUN83	.	9.240	A	T	831.00		.	.	.	89.94
10JUN83 – 24JUN83	.	9.300	A	T	837.00		.	.	.	90.00
24JUN83 – 06JUL83	.	9.700	A	T	873.00		.	.	.	90.00
05JUL83 – 20JUL83	.	9.700	A	T	873.00		.	.	.	90.00
20JUL83 – 02AUG83	.	9.600	A	T	864.00		.	.	.	90.00
02AUG83 – 11AUG83	.	9.370	A	T	843.00		.	.	.	89.97
11AUG83 – 11OCT83	.	9.660	A	T	869.00		.	.	.	89.96
11OCT83 – 01NOV83	.	10.740	A	T	966.00		.	.	.	89.94
23MAR84 – 26APR84	.	8.460	A	T	761.00		.	.	.	89.95
26APR84 – 23MAY84	.	6.760	A	T	608.00		.	.	.	89 94
23MAY84 – 01JUN84	.	8.920	A	T	838.00		.	.	.	93.95
01JUN84 – 21JUN84	.	9.030	A	T	848.00		.	.	.	93.91
21JUN84 – 05JUL84	.	8.180	A	T	768.00		.	.	.	93.89
05JUL84 – 18JUL84	.	9.520	A	T	894.00		.	.	.	93.91
18JUL84 – 02AUG84	.	9.820	A	T	923.00		.	.	.	93.99
02AUG84 – 14AUG84	.	7.920	A	T	744.00		.	.	.	93.94

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
				SAS						
14AUG84 - 19SEP84	.	7 840	A	T	736.00		.	.	.	93.88
19SEP84 - 04OCT84		8 180	A	T	768 00		.	.	.	93.89
04OCT84 - 08NOV84		9 400	A	T	883.00		.	.	.	93.94
08NOV84 - 20NOV84		8 380	A	T	787 00		.			93 91
26APR85 - 12JUN85	.	9 760	A	T	917 00			.	.	93.95
12JUN85 - 26JUN85	.	9.200	A	T	1058.00		.	.	.	115.00
26JUN85 - 05JUL85	.	7 420	A	T	853.00		.	.	.	114.96
05JUL85 - 17JUL85	.	9 040	A	T	1039.00		.	.	.	114.93
17JUL85 - 31JUL85	.	8 980	A	T	1032.00		.	.	.	114 92
31JUL85 - 14AUG85		9.640	A	T	1108.00		.	.	.	114.94
14AUG85 - 23AUG85	.	6.800	A	T	782.00		.	.	.	115.00
23AUG85 - 26SEP85		8.800	A	T	1012.00		.	.	.	115.00
26SEP85 - 04NOV85	.	9 020	A	T	1037 00		.	.	.	114.97
04NOV85 - 20NOV85	.	9.500	A	T	1092.00		.	.	.	114 95

ACCOUNT-NUMBER 944157 METER-NUMBER 1 FUEL E

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
10APR85 - 06JUN85	.	0.000	A	KWH	14.00	ND5	.	.	.	.
06JUN85 - 31JUL85	.	0.000	A	KWH	14.00	ND5	.	.	.	.
31JUL85 - 24SEP85	.	0 000	A	KWH	14.00	ND5	.	.	.	.
24SEP85 - 21NOV85	.	0 000	A	KWH	14.00	ND5	.	.	.	.
10NOV85 - 09APR86	.	0 000	A	KWH	14.00	ND5	.	.	.	.
21NOV85 - 10FEB86	.	0.000	A	KWH	14.00	ND5	.	.	.	.
25SEP81 - 24NOV81	.	0.000	A	KWH	3.00	101	.	.	.	.
02AUG82 - 27SEP82	.	0.000	A	KWH	4.00	101	.	.	.	.
09JUN83 - 28SEP83	.	0.000	A	KWH	8.00	101	.	.	.	.
28SEP83 - 13FEB84	.	0.000	A	KWH	4.00	101	.	.	.	.
13FEB84 - 06APR84	.	0.000	A	KWH	6.00	101	.	.	.	.
06APR84 - 07JUN84	.	0.000	A	KWH	6.00	101	.	.	.	.
07JUN84 - 02AUG84	.	0.000	A	KWH	6.00	101	.	.	.	.
02AUG84 - 26SEP84	.	0.000	A	KWH	6.00	101	.	.	.	.
26SEP84 - 23NOV84	.	0.000	A	KWH	6.00	101	.	.	.	.
23NOV84 - 11FEB85	.	0.000	A	KWH	6.00	101	.	.	.	.
11FEB85 - 10APR85	.	0.000	A	KWH	7.00	101	.	.	.	.

ACCOUNT-NUMBER 944157 METER-NUMBER 5930910 FUEL E

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
10FEB86 - 09APR86	.	0.000	A	KWH	14.00		.	.	.	.
09APR86 - 04JUN86	.	0.000	A	KWH	14.00		.	.	.	.
04JUN86 - 30JUL86	.	0.000	A	KWH	14.00		.	.	.	.
30JUL86 - 24SEP86	.	3.000	A	KWH	13.00		433.33	.	.	.

ACCOUNT-NUMBER 944521 METER-NUMBER 1 FUEL E

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
10APR85 - 06JUN85	.	34750 000	A	KWH	2577.00	ND5	7.42	.	.	.
06JUN85 - 31JUL85	.	47280 000	A	KWH	3501.00	ND5	7.40	.	.	.
31JUL85 - 24SEP85	.	32980.000	A	KWH	2446.00	ND5	7 42	.	.	.
24SEP85 - 21NOV85	.	32110.000	A	KWH	2382.00	ND5	7.42	.	.	.
10NOV85 - 09APR86	.	30080.000	A	KWH	2233.00	ND5	7.42	.	.	.
21NOV85 - 10FEB86	.	24580.000	A	KWH	1827.00	ND5	7.43	.	.	.
25SEP81 - 24NOV81	.	27450.000	A	KWH	1549.00	101	5.64	.	.	.
02AUG82 - 27SEP82	.	29160.000	A	KWH	1826.00	101	6.26	.	.	.
09JUN83 - 03AUG83	.	47720.000	A	KWH	2988.00	101	6 26	.	.	.
03AUG83 - 28SEP83	.	28630.000	A	KWH	1793.00	101	6.26	.	.	.
28SEP83 - 25NOV83	.	28490.030	A	KWH	1784.00	101	6.26	.	.	.
25NOV83 - 13FEB84	.	23320.000	A	KWH	1460.00	101	6.26	.	.	.
13FEB84 - 06APR84	.	25340.000	A	KWH	15[illegible]2.00	101	6 28	.	.	.
06APR84 - 07JUN84	.	36410.000	A	KWH	220[illegible].00	101	6 04	.	.	.
02AUG84 - 26SEP84	.	31110.000	A	KWH	185[illegible].00	101	5.97	.	.	.
26SEP84 - 23NOV84	.	30090.030	A	KWH	1795.00	101	5.97	.	.	.
23NOV84 - 11FEB85	.	22230.000	A	KWH	13[illegible]8.00	101	5.97	.	.	.
11FEB85 - 10APR85	.	30850.000	A	KWH	1897.00	101	6.15	.	.	.

LISTING OF ALL SCHOOLS DATA BY SSPRINT2

BILLS UNDER $12 ARE NOT CHECKED.

FOR CHANGED M=MISSING VALUE L=COST PER UNIT<0 2•25% QUARTILE G=COST PER UNIT>2•75% QUARTILE. A=EX LOTUS

SCHOOL Cashmere High School

ACCOUNT-NUMBER 944521 METER-NUMBER 5931282 FUEL E

DATE	METER-READING	ENERGY-USE	CHANGE	UNITS	COST	TARRIF	c/KWh	$/GJ	$/LITRE	$/TONNE
10FEB86 - 09APR86	.	30080.000	A	KWH	2233 00		7.42	.	.	.
09APR86 - 04JUN86	.	37420.000	A	KWH	2911.00		7.78	.	.	.
24SEP86 - 21NOV86	.	34720 000	A	KWH	2945 00		8.48	.	.	.
04JUN86 - 30JUL86	.	63490 000	A	KWH	4930 00	NDS	7.77	.	.	.
30JUL86 - 24SEP86	.	48220.000	A	KWH	3748.00	NDS	7.77	.	.	.

LISTING OF ALL SCHOOLS DATA BY SSPRINT2
FOR SPAN F=FULL YEARS ACCOUNTS, N=OVER HALF A YEAR
AND I=LESS THAN HALF A YEAR
FOR MISS, N=NO ACCOUNTS MISSING Y=ACCOUNTS MISSING
AMOUNT AND COST ARE JUST THE SUMS OF AVAILABLE ACCOUNTS
WHICH ARE SPLIT LINEARLY FOR OVERLAPPING YEARS

SCHOOL Cashmere High School

SUMMARY LISTING OF ENERGY CONSUMPTION AND COST

ACCOUNTS FOR YEAR 1981

ACCOUNT	METER	SPAN	MISS	PERIOD	TAR	AMOUNT (GJ)	COST	c/KWh	$/GJ	$/LITRE	$/TONNE
369617		F	N	08OCT81 - 08OCT81		244 640	800.00	.	.	.	71.94
944157	1	I	N	25SEP81 - 24NOV81	10	0 000	3.00	.	.	.	.
944521	1	I	N	25SEP81 - 24NOV81	10	98 820	1549.00	5.64	.	.	.

	AMOUNT (GJ)	COST
GAS TOTAL	0 000	0.00
ELECTRICITY TOTAL	98.820	1552.00
OIL TOTAL	0.000	0 00
COAL TOTAL	244 640	800.00
ALL FUELS TOTAL	343 460	2352.00

ACCOUNTS FOR YEAR 1982

ACCOUNT	METER	SPAN	MISS	PERIOD	TAR	AMOUNT (GJ)	COST	c/KWh	$/GJ	$/LITRE	$/TONNE
369617		F	Y	22APR82 - 19OCT82		2302.080	8089.00	.	.	.	77.30
944157	1	I	N	02AUG82 - 27SEP82	10	0.000	4.00	.	.	.	.
944521	1	I	N	02AUG82 - 27SEP82	10	104.976	1826.00	6.26	.	.	.

	AMOUNT (GJ)	COST
GAS TOTAL	0.000	0.00
ELECTRICITY TOTAL	104.976	1830.00
OIL TOTAL	0.000	0 00
COAL TOTAL	2302 080	8089.00
ALL FUELS TOTAL	2407.056	9919.00

ACCOUNTS FOR YEAR 1983

ACCOUNT	METER	SPAN	MISS	PERIOD	TAR	AMOUNT (GJ)	COST	c/KWh	$/GJ	$/LITRE	$/TONNE
369617		F	Y	24FEB83 - 11OCT83		2253.020	9111.00	.	.	.	88.97
944157	1	N	N	09JUN83 - 31DEC83	10	0.000	10.72	.	.	.	.
944521	1	N	N	09JUN83 - 31DEC83	10	415.202	7222.00	6.26	.	.	.

	AMOUNT (GJ)	COST
GAS TOTAL	0.000	0.00
ELECTRICITY TOTAL	415.202	7232.72
OIL TOTAL	0.000	0.00
COAL TOTAL	2253.020	9111.00
ALL FUELS TOTAL	2668.222	16343.72

ACCOUNTS FOR YEAR 1984

ACCOUNT	METER	SPAN	MISS	PERIOD	TAR	AMOUNT (GJ)	COST	c/KWh	$/GJ	$/LITRE	$/TONNE
369617		F	Y	23MAR84 - 08NOV84		2253.020	9556 00	.	.	.	93 33
944157	1	F	N	01JAN84 - 31DEC84	10	0.000	34.13	.	.	.	.
944521	1	N	Y	01JAN84 - 31DEC84	10	526.807	8877.80	6.37	.	.	.

	AMOUNT (GJ)	COST
GAS TOTAL	0.000	0.00
ELECTRICITY TOTAL	526.807	8911.93
OIL TOTAL	0.000	0.00
COAL TOTAL	2253.020	9558.00
ALL FUELS TOTAL	2779.827	18469 93

LISTING OF ALL SCHOOLS DATA BY SSPRINT2
FOR SPAN F=FULL YEARS ACCOUNTS. N=OVER HALF A YEAR
AND I=LESS THAN HALF A YEAR
FOR MISS, N=NO ACCOUNTS MISSING Y=ACCOUNTS MISSING
AMOUNT AND COST ARE JUST THE SUMS OF AVAILABLE ACCOUNTS
WHICH ARE SPLIT LINEARLY FOR OVERLAPPING YEARS

SCHOOL Cashmere High School

ACCOUNTS FOR YEAR 1985

ACCOUNT	METER	SPAN	MISS	PERIOD	TAR	AMOUNT (GJ)	COST	c/KWh	$/GJ	$/LITRE	$/TONNE
369617		F	Y	26APR85 - 04NOV85		1939 520	9930 00	.	.	.	112.64
944157	1	N	N	10APR85 - 31DEC85	ND	0.000	60.76		.	.	.
944157	1	I	N	21NOV85 - 31DEC85	ND	0 000	6.91	.	.	.	.
944157	1	I	N	01JAN85 - 10APR85	10	0 000	10.15	.	.	.	.
944521	1	N	N	10APR85 - 31DEC85	ND	566 450	11665.22	7.41	.	.	.
944521	1	I	N	21NOV85 - 31DEC85	ND	43.698	902.22	7.43	.	.	.
944521	1	I	N	01JAN85 - 10APR85	10	153.075	2594.20	6.10	.	.	.

	AMOUNT (GJ)	COST
GAS TOTAL	0.000	0.00
ELECTRICITY TOTAL	763.223	15239.46
OIL TOTAL	0 000	0.00
COAL TOTAL	1939.520	9930 00
ALL FUELS TOTAL	2702.743	25169.46

ACCOUNTS FOR YEAR 1986

ACCOUNT	METER	SPAN	MISS	PERIOD	TAR	AMOUNT (GJ)	COST	c/KWh	$/GJ	$/LITRE	$/TONNE
		F	Y	06MAY86 - 12OCT86		2508.440	14321.00	.	.	.	125.60
944157	1	I	N	01JAN86 - 09APR86	ND	0.000	9.24	.	.	.	.
944157	1	I	N	01JAN86 - 10FEB86	ND	0.000	7.09	.	.	.	.
944157	5930910	N	N	10FEB85 - 24SEP85		0.011	55.00	1800.00	.	.	.
944521	1	I	N	01JAN86 - 09APR86	ND	71.470	1473.78	7.42	.	.	.
944521	1	I	N	01JAN86 - 10FEB86	ND	44.790	924.78	7.43	.	.	.
944521	5931282	N	Y	10FEB86 - 21NOV86		367.992	8889.00	7.91	.	.	.
944521	5931282	I	N	04JUN86 - 24SEP86	ND	402.156	8676.00	7.77	.	.	.

	AMOUNT (GJ)	COST
GAS TOTAL	0.000	0.00
ELECTRICITY TOTAL	886.419	19236 89
OIL TOTAL	0.000	0.00
COAL TOTAL	2508.440	14321.00
ALL FUELS TOTAL	3394.859	33557.89

LISTING OF ALL SCHOOLS DATA BY SSPRINT2
NORMALISED ENERGY IS FOR ACCOUNTS INTERPOLATED LINEARLY TO
COVER THE WHOLE YEAR
CLASS No FOR 1980, UNTIL 1984 WHEN WE USE CLASS85 VALUES

SCHOOL Cashmere High School

RAW ENERGY USE

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	CLASS 80	AREA	CLASS 85
$/CR	0.00	0.00	0.00	0.00	38 56	162.61	267.93	302.79	412 61	550 13	61	10269	61
GJ/CR	0.00	0.00	0.00	0.00	5.63	39.46	43.74	45.57	44 31	55.65	61	10269	61
$/m*m	0.00	0.00	0.00	0.00	0 23	0.97	1.59	1.80	2.45	3.27	61	10269	61
MJ/m*	0.00	0.00	0 00	0.00	33 45	234.40	259.83	270.70	263 19	330.59	61	10269	61

NORMALISED ENERGY USE - USE WITH CARE

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	CLASS 80	AREA	CLASS 85
$/CR	0.00	0.00	0.00	0.00	38.56	162.61	267.93	302.79	412 61	2200.52	61	10269	61
GJ/CR	0.00	0.00	0.00	0.00	5 63	39.46	43.74	45.57	44 31	222.61	61	10269	61
$/m*m	0.00	0.00	0.00	0.00	0.23	0.97	1.59	1.80	2.45	13.07	61	10269	61
MJ/m*	0 00	0.00	0.00	0.00	33.45	234.40	259.83	270.70	263.19	1322.37	61	10269	61

LISTING OF ALL SCHOOLS DATA BY SSPRINT2
SUMS ARE OF RAW ACCOUNT DATA

GRAND TOTAL ENERGY CONSUMPTION AND COST

YEAR	FUEL	AMOUNT	COST
	GAS	0.000	0.00
1981	ELECTRICITY	98.820	1552 00
	OIL	0 000	0.00
	COAL	244 640	800 00
	TOTAL	343.460	2352.00
	GAS	0.000	0.00
1982	ELECTRICITY	104 976	1830.00
	OIL	0.000	0.00
	COAL	2302.080	8089.00
	TOTAL	2407.056	9919.00
	GAS	0.000	0.00
1983	ELECTRICITY	415 202	7232.72
	OIL	0.000	0.00
	COAL	2253.020	9111.00
	TOTAL	2668.222	16343.72
	GAS	0.000	0.00
1984	ELECTRICITY	526.807	8911.93
	OIL	0.000	0.00
	COAL	2253.020	9558.00
	TOTAL	2779 827	18469.93
	GAS	0.000	0.00
1985	ELECTRICITY	763.223	15239.46
	OIL	0.000	0.00
	COAL	1939.520	9930.00
	TOTAL	2702.743	25169.46
	GAS	0.000	0.00
1986	ELECTRICITY	886.419	19236.89
	OIL	0.000	0.00
	COAL	2508.440	14321.00
	TOTAL	3394.859	33557.89

Appendix II

M.W.D. Summary Reports

The following two reports are reproduced in this Appendix:

Energy Management Activities At Rongotai College and Wellington College. November 1986. W. Brander, Wellington for G.B.E.M.P..

Optimisers In High Schools - Cashmere and Hillmorton. 5 May 1987. R.J. McAlister, Christchurch

OPTIMISERS IN HIGH SCHOOLS

CASHMERE AND HILLMORTON

Contents

1 Introduction

2 Background

3 School Selection

4 Hillmorton Installation

5 Cashmere Installation

6 Observations

7 Conclusion

Prepared by: R J McAllister

Date: 5 May 1987
File: ME2/129 and E02-002

1 INTRODUCTION

As part of a study carried out by the Energy Research Group (ERG) of the Victoria University of Wellington to determine energy savings through the use of improved boiler controls, optimisers were installed in two Christchurch high schools for the winter of 1986.

This report summarises the installation of the optimisers and comments are made on the project together with some of the problems encountered.

2 BACKGROUND

The ERG was contracted by the Department of Education to establish a programme to demonstrate the financial benefits of improved energy management in schools.

Their proposals included the installation of optimisers in six Christchurch secondary schools at an estimated cost of $25,000 The trial period would be over the winter period of 1986.

The Ministry of Works and Development, Christchurch, was approached in November 1985 to assist in this venture. The request for assistance was to include:

- Provide technical assistance in the selection of schools
- Obtain estimates from equipment suppliers and provide overall estimates for the complete installations.
- Supervise installation and commissioning.
- Provide technical assistance, if and when required, to caretakers during the exercise.

The selection of the particular optimiser was made by the ERG (Satchwell SMT and Honeywell W989A) and were selected on the basis that both were of similar cost, performed similar functions and had "a record of proven New Zealand use".

SCHOOL SELECTION

From a list of eight schools, all of which were visited by staff from MWD on and 18 March 1986, a short list of five schools was made, namely:

- Cashmere
- Hagley
- Hillmorton
- Kaiapoi
- Papanui

Quotations were then received from GEC (Satchwell agents) and Honeywell. Due mainly to the high cost of installation of sensor wiring from the boilerhouse to selected lassrooms and the requirement for MWD to charge for all services, the initial proposal to install six optimisers was reduced to two (Cashmere and Hillmorton).

To obtain as much information as possible ERG also monitored the existing systems at Papanui and Linwood. The ERG installed data loggers to record a limited amount of information at these four High Schools.

Financial authority to proceed finally arrived in Christchurch on 6 June 1986 from the Department of Education.

HILLMORTON INSTALLATION

During the visit to this school in April with a representative from GEC it was noticed that a new switchboard was being installed. Following discussions with the Contractor, the design was modified to replace the simple time clock control system with an optimiser.

It was programmed as an on/off unit until the indoor and outdoor sensors were installed.

The cost of a permanent installation of the sensor wiring to the classrooms was prohibitive and it was agreed with the ERG that a

temporary connection be made. The two temporary catenary wires will need to be removed and a more permanent connection considered at a later date.

It became obvious after a short period of optimiser control that all was not well with the boiler control system It was only after a concerted effort by MWD staff spread over several weeks that it was possible for the boilers, pumps and controls to function correctly

5. CASHMERE INSTALLATION

It was the intention of the ERG to install a Honeywell W989A Optimiser at one of the selected schools. However, late in May 1986 we were notified by Honeywell that these units were superseded and could only be purchased on indent with a delivery time of approximately eight weeks.

A recommendation to install a Honeywell Omnitrol W7032A controller was agreed to by the ERG although it was not a tried and proved system in New Zealand. The cost of this optimiser was approximately half that of the originally selected W989A controller

As this unit also had facilities to provide temperature compensation, a water flow sensor was installed to control the existing 3 way valve.

The indoor sensor wiring was a permanent installation, using the covered walkways as the means for running the cables from the boilerhouse to the classrooms.

Although the problems at this school were different to those at Hillmorton there was equally as much MWD involvement in overcoming the problems at this school.

Some of the problems were:

- Incorrect operation of the over-riding facility by the Caretaker on several occasions. Some of these programming errors were not picked up until the next weekly visit by Honeywell staff.

- Poor quality coal. The school changed the supplier twice which resulted in the use of different types of coal during the early part of the trial period.

- Wide variations in boiler start times when outdoor temperatures suggested otherwise.

This problem was largely resolved when control of the manually operated fan convector switch in the selected classroom was taken away from the classroom teacher.

This remedy was only a temporary measure and will require a permanent solution.

OBSERVATIONS

During the trial period comments and opinions were expressed from all those connected with the exercise. These are summarised as follows:

(a) The Satchwell SMT was more "user friendly" than the Honeywell Omnitrol.

(b) One of the good features of the Omnitrol is that it stores 28 days of information. whereas the Satchwell stores only "this day" data.

(c) Most high schools consist of several blocks of very different construction and hence have very different thermal characteristics. It is difficult to install a system to cater for these differences.

(d) Should the indoor sensor be placed in the coldest room? The average room? The room with the most solar gain. etc?

(e) If the optimiser is used to control the period for night classes then one of the monitored classrooms must be one that is used at night. This could often compromise the selection of the "best" classroom.

(f) Optimisers give good results at the start and finish of the heating season when the outside temperatures are likely to vary the most.

(g) The cost of installation in most cases is higher than the cost of the optimiser.

The installation of an optimiser should be considered when there is a major re-cabling projec in a school.

(h) Different heating systems within the same school provides control problems as each system has its own thermal characteristic.

Which system should be monitored? The quickest? The slowest? The average?

(i) It is imperative that the control setting of a room thermostat is higher than the optimiser "ON TEMPERATURE" when the thermostat is controlling the temperature in any of the monitored classrooms.

This was overlooked in a high school outside the study and it caused many control problems before it was altered

(j) At Linwood High, the outdoor sensors for the temperature compensator are placed high on a wall facing north east with no apparent cover to limit solar gain. As a result the three way valve was shutting down reducing the flow when the temperature in the monitored classroom was not up to the control setting.

Under these conditions the optimiser was starting the boilers at its maximum pre start time. ie. 0230 hours

(k) Many of the problems encountered during this study were control problems unrelated to the fitting of optimisers, and were identified because attention was given to the heating system as a whole.

CONCLUSION

At a very early stage in the project it seemed to the writer that the "cart was before the horse", that is, improved boiler controls were being fitted to gauge cost effectiveness when the existing plant was not functioning efficiently.

If the heating system itself is not operating efficiently under effective control, then any savings made through the use of an optimiser can be significantly reduced by wasteful use of fuel during the day.

The emphasis for 1986 could have been to ensure that at each school all plant was operating satisfactorily and that all relevant parameters, including boiler efficiency, be carefully monitored for future comparisons.

The optimisers could then have been installed in 1987 and the same parameters measured and compared with those of 1986. The full benefit of the optimiser could then be realised and that not only could savings be made, there would also be an improved level of comfort particuarly at the ends of the heating season.

6MF4.121G

ENERGY MANAGEMENT ADVISORY SERVICE

TO ENERGY RESEARCH GROUP
School of Architecture
Victoria University of Wellington
Private Bag
WELLINGTON

AND DEPARTMENT OF EDUCATION
Head Office
WELLINGTON

ENERGY MANAGEMENT ACTIVITIES AT RONGOTAI COLLEGE AND WELLINGTON COLLEGE

REPORT COMPILED BY: W BRANDER, NOVEMBER 1986

MINISTRY OF WORKS AND DEVELOPMENT
MECHANICAL AND ELECTRICAL ENGINEERING DIRECTORATE
PRIVATE BAG
WELLINGTON

FILE: 13/1/47
17/413/M6190

6MF4.122G

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1 Summary of Energy Management Actions

2 Introduction

3 Rongotai College

3.1 Replacement of Optimiser

3.2 Recommission Compensator Controls

3.3 Check and adjust air/fuel mixture to boilers

3.4 Timer Switch for Audio-visual room heating

4 Wellington College

4.1 Check switchboard

4.2 Inspection of pneumatic controls and compensator circuits

4.3 Check and adjust air/fuel mixture, clean boilers

4.4 Electric load monitoring

4.5 Boiler conversion to natural gas

R44 - 103

1 SUMMARY

Rongotai College

1 The optimiser has been replaced and commissioned.

2 The compensator controls have been checked and recommissioned.

3 The boiler air/fuel ratios have been adjusted but cleaning has been deferred until the end of the heating season.

4 The timer-switch has been fitted in the Audio-visual room.

Wellington College

1 The boiler timeswitch controls have been reset but school staff are bypassing them because of the poor performance of the heating system.

2 The pneumatic controls on the fan coil units and the compensator controls have been examined. It is recommended that basic cleaning and maintenance of the fan coil units be carried out and the compensator controls replaced. This should improve the performance of the heating system considerably. The estimated cost of this work is $10,000.

3 The boilers have been cleaned and fuel/air mixtures adjusted.

4 The night time electrical loads have been identified and recommendations to reduce these are made.

5 The Wellington Gas Company can only provide sufficient gas to supply one boiler. A proposal is put forward to convert one boiler at a cost of $26,000 + GST. Energy cost savings are estimated to be at least $10,000.

Wellington Girls College

1 A list of suitable companies to remove redundant oil has been given to Department of Education, CRO.

2 INTRODUCTION

This report describes progress on the Energy Management Work in three Wellington Secondary Schools requested by the Department of Education, Head Office on 23 July 1986 (Department of Education ref. 7/36/110).

The work has been carried out in conjunction with a monitoring project conducted by the Energy Research Group, School of Architecture, Victoria University. This report follows individual energy audit reports on Rongotai College, Wellington College, and Wellington Girls College, and a boiler efficiency report for the three colleges.

The following sections correspond to the actions listed in the minutes of the meeting between Department of Education, Ministry of Works and Development, and the Energy Research Group of 2 July 1986.

3 RONGOTAI COLLEGE

3.1 Replacement of Optimiser

A Satchwell SMT Optimiser has been installed in the boiler house. Two room sensors have been used to measure indoor temperature, one located in a classroom, the other in an office. The outside sensor is located above the boiler house door.

The optimiser was commissioned on 30 September and preliminary settings were made. As the optimiser is "self-learning" a settling period is to be expected. The College Caretaker, Mr M Hearn has been given instructions on his particular functions with the optimiser.

3.2 Recommission Compensator Controls

The compensator controls have been checked and the components were found to be in working order. The controls have been recommissioned and should now be providing satisfactory regulation of the hot water flow temperature to room radiators.

3.3 Check and Adjust Air/Fuel Mixture to Boilers

The gas train on Boiler 1 has been replaced under maintenance, and combustion checks were made on the boilers. Air/fuel mixture was adjusted. Cleaning of the combustion chambers is required but this will be deferred until the end of the heating season.

3.4 Timer Switch for Audio-visual Room Heating

The timer-switch has been fitted and is operational.

4 WELLINGTON COLLEGE

4.1 Check Switch Board

The time switches controlling the boilers have been re-set and are operating. However, the boilers are continuing to operate on a 24-hour basis as school staff attempt to keep those blocks served by the main boilers warm. This problem is discussed in 4.2 below.

4.2 Inspection of Pneumatic Controls and Compensator Circuits

The pneumacic contols for the fan convectors in the tower block and S68 block have been examined. A number of wall thermostats are defective and the air lines are leaking. It has not been possible to accurately estimate the cost of correction in the tower block where access to pneumatic lines is restricted. In the S68 block access to the pneumatic circuits is better. The expected cost of repair is between $15,000 and $30,000.

The Satchwell compensator controls in the ground floor plant room of the tower block are not functioning correctly. The suppliers of these controls advise that it is not worth repairing them but that new replacement controls are available. The estimated cost of supply, installation and commissioning of new controls together with replacement of all sensors, actuators and valves is $7,500.

The lack of heating in the tower block and S68 block is caused by the malfunctioning compensator controls which govern the water temperature to each block, the faulty pneumatic controls for the fan convector units, and the dirt and rubbish in the units themselves which adversely affect airflow. The cost of cleaning and resetting dampers on these units is estimated to be $2,500.

It is recommended that all the fan coil units are cleaned and the dampers on these units set in the recirculating position. In conjunction with this work the compensator controls should be replaced. This will improve the heat output from the system and should eliminate the need to manually by-pass the timeswitch control of the boilers.

4.3 Check and Adjust Air/fuel Mixtures and Clean Boilers

The above actions were carried out on both boilers and combustion efficiencies were raised to expected levels. The boilers should both be checked again over the summer and adjusted and cleaned as necessary.

4.4 Electrical Load Monitoring

The sub-main loads fed from the main switchboard were monitored over a 10 day period from 24 July. These loads were summated and compared with the total mains load. Monitoring was restricted to a single phase for convenience. The results are shown in Figures 1 and 2 which show the composition of the total electrical load on a single phase at 24:00, 06:00, 12:00 and 18:00. The major sub-mains loads (in energy terms) are the canteen, the unmetered supply to the squash courts, etc., the Rising Main Light, DB MP, and HA Light (note that the 'Headmaster' submain is a single phase supply). At night the most significant of these are the Canteen, HA Light, DB MP and Rising Main Lighting.

The Canteen includes the freezer equipment in the building and the supply to the prefabs. The electric space heating in the prefabs would contribute to this after-hours load if it is being left on at nights.

HA Lights, and the rising main lighting which serves the Tower Block are large after-hours energy consumers because of the night cleaning shift.

DP MP serves the mechanical plant in the ground floor plant room of the Tower Block i.e., the air compressor for the pneumatic controls and the circulating pumps for each heating zone. This equipment is operating continuously at present. However, the pneumatic controls are not functioning and therefore the compressor is not required. The circulating pumps operate continuously because the boiler timeswitch controls have been bypassed so that the boilers operate continuously on demand.

4.5 Boiler Conversion to Natural Gas

The present gas supply to the College is through a 100 mm main from the Dufferin St entrance. This reduces to 50 mm before entering the tower block from where a riser supplies the laboratories in the building.

The Wellington Gas Company has been approached regarding the supply of gas to the College. At present they can only supply 66 m^3/hr at 1 kPa. With this quantity of gas only one boiler could be converted. The pressure drop in the length of 50 mm main would result in insufficient gas pressure at the boiler house for the gas burners. To avoid replacing this main a gas booster would be installed in the tower block to raise the gas pressure to the burners.

Following negotiation with the Gas Company agreement has been reached to install a gas booster subject to certain conditions.

Our proposal is to convert one of the two boilers to gas and make this the lead boiler. It is anticipated that this boiler would supply 70% - 100% of the College's annual heating energy. The second boiler would remain on oil and would operate if required only at times of high heating demand. This is seen as an interim measure and a formal request should be made to the Gas Company to provide additional gas.

The estimated savings from conversion listed below are based on present consumption:

1	Assuming 70% gas	30% oil consumption	=	$12,100 p.a.
2	Assuming 85% gas	15% oil consumption	=	$16,200 p.a.
3	Assuming 100% gas	0% oil consumption	=	$19,900 p.a.

However, improvements to the heating system recommended in Section 4.2 should reduce the boiler operation substantially. With these changes it is estimated that energy cost savings will still be at least $10,000 per year.

The cost of conversion including MWD fees for contract supervision are estimated to be $26,000.00 (GST not included).

Conversion Details

1 The Hoval TKD 500 boilers have a high combustion chamber flow resistance and require a burner which is capable of matching this resistance. An imported burner would be required and price is subject to exchange rates.

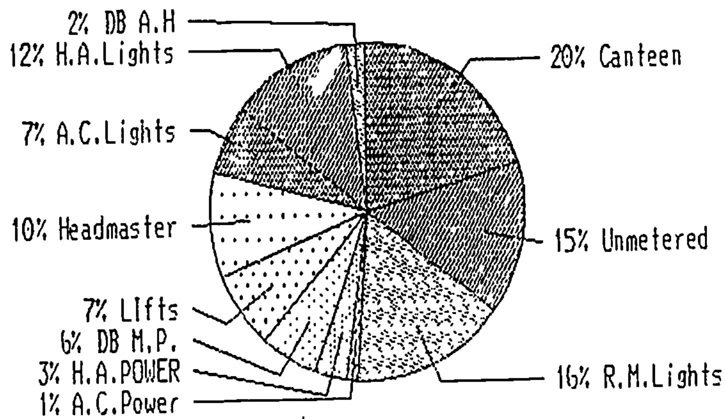
2 Install gas booster in boiler room, provide additional riser from ground floor to boiler room connect in booster and valve train.

3 Install a non-return valve on existing riser at ground floor which serves laboratories.

4 Clean boiler and flue replace both main and explosion door seals, remove existing burner, fit new gas burner, remove redundant wiring from boiler control cabinets, wire in new burner. Provide condensate drains.

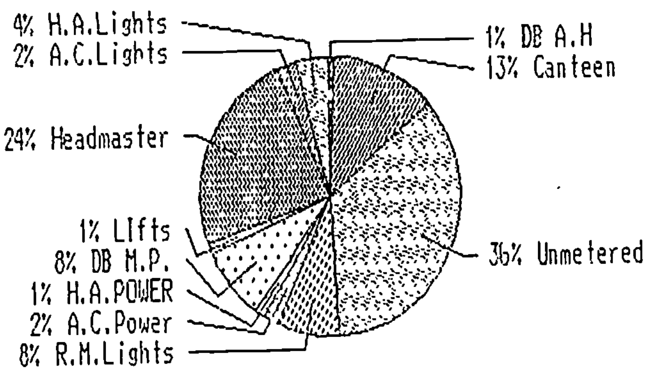
5 Commission booster and burner and supply operation and maintenance manual.

WELLINGTON COLLEGE
ELECTRICAL SUB MAINS LOADS



12:00

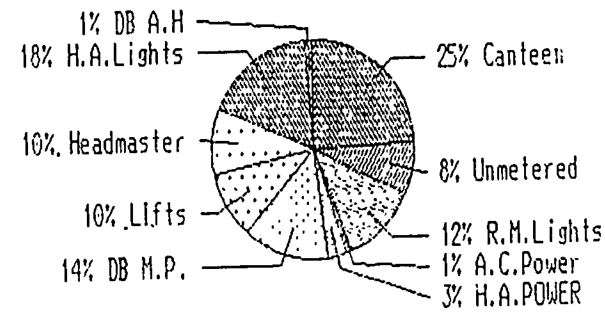
TOTAL LOAD 244 Amps



18:00

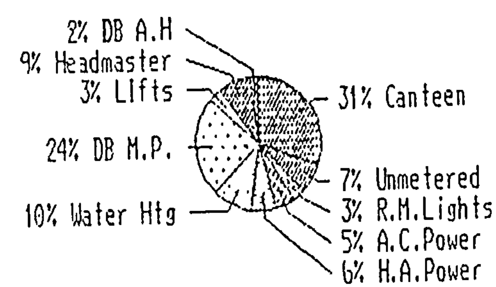
TOTAL LOAD 168 Amps

WELLINGTON COLLEGE
ELECTRICAL SUB MAINS LOADS



24:00

TOTAL LOAD 102 Amps



time 06:00

TOTAL LOAD 40 Amps