Appendix E - Calculations of Energy Savings

E.1.Electricity tariff analysis

According to the electricity meter readings supplied by BloggsPower, the Bloggsville Motor Inn is on the “Time of Use” electricity tariff.

As listed in Appendix A, under the Time of Use tariff, the annual electric energy use is 508,816 kWh/ year, at an annual total cost of **$38,788/year**. This gives an average price of 7.62¢/ kWh.

This is a quite low price, as evidenced by comparison with the alternative options.

By comparison, at the Standard Tariff rate of 9.95 ¢/ kWh, the annual electric energy cost would be:

(508,816 kWh/ yr) x ($0.0995/ kWh) = **$50,627/year**

And, on the Day/ Night Tariff of 11.52¢/ kWh for day time units and 5.25 ¢/ kWh for night time units, the annual electric energy cost would be:

Day	(377,098 kWh/ yr) x ($0.1152/ kWh)	= $43,442/ year
Night	(131,718 kWh/ yr) x ($0.0525/ kWh)	= $6,915/ year
Total	(508,816 kWh/ yr)	= **$50,356/year**

With the deregulated retail electricity market, there may be savings in energy costs by tendering competitively for electricity and gas supplies. But this requires a reasonable amount of analysis and negotiation, which is beyond the scope of this report.

E.2.Reduce thermostat setpoint

The three heating thermostats in the facility were all set to about 23°C. This is a warm temperature, probably well above that necessary for comfort in wintertime.

The present gas space heating energy use is given in Appendix D as 317,550 kWh/ year.

The heating energy use is proportional to the "heating degree-days" a measure of how cold it was for how long.

If we assume that the indoor temperature is kept 2 C° warmer than outside because of internal heat gains (waste heat), then the balance temperature of the building is about 21°C. In Bloggsville according to Met office statistics, there are 2900 heating degree-days/ year below this base temperature.

If the internal temperature is reduced to 20°C (still very comfortable, by most standards) then the balance temperature will be reduced to 18°C. The Bloggsville heating degree days below 18°C are about 2100 degree-days per year (the same as Wellington).

The energy savings then are the difference between these two sets of degree-days, or

[(2900–2100)/ 2900] x 317,550 kWh/ year = **87,600 kWh/year**

This would be worth:

87,600 kWh/ year x $0.031/ kWh = **$2,715/year (say $2,700/yr)**

E.3.Reduce thermostat accessibility

The thermostats controlling the temperature to which the building is heated are in plain view, exposed to occupant intervention. As building occupants rarely have experience in controlling temperatures, they often over-compensate when they are cold, and end up overheating the building. For this reason, it is recommended that thermostats be kept away from occupant intervention.

In this case, this might make a 0.5C° difference in average temperature throughout the year. The savings from this would be the difference in degree days, or 150 (assuming 300 days of heating, and 0.5°C temperature increase).

[(150)/ 2900] x 317,550 kWh/ year = **16,400 kWh/year**

If this was done after the temperature was reduced, the savings would still be:

[(150)/ 2100] x [317,550 – 87,600] kWh/ year = **16,400 kWh/year**

This would be worth:

16,400 kWh/ year x $0.031/ kWh = **$509/year (say $500/year)**

Three thermostat cover plates would cost about $50 each to install, giving a "simple payback" of about 0.3 years, corresponding to a rate of return of 330%/ year.

E.4. Install timer on boilers

The restaurant and public bar appear to be heated 24 hours/ day, even when they are unoccupied. If they were on a timer, so they were only heated from a few hours before they were occupied until they were closed for the night, significant heating energy savings could occur.

As it is coldest at night, most of the heating load occurs then. Although the restaurant is open 17 hours/ day, from 7 AM until 10 PM, if the heating was turned off between 10 PM and 5 AM, probably 40% energy savings would occur. Likewise, in the Bar, if heating was turned off between 10 PM and 9 AM, probably 60% energy savings would occur.

If each of these used one third of the heating for the whole facility, then the restaurant's saving would be:

(1/ 3) x (317,550 kWh/ year) x 40% = **42,340 kWh/year**

This would be worth:

42,340 kWh/ year x $0.031/ kWh = **$1312/year (say $1,300/year)**

If the restaurant temperature had been reduced to 20°C (as discussed in E.2), this would have reduced the heating energy use to:

317,550 kWh/ year – **87,600 kWh/year = 229,950 (say 230,000) kWh/yr**

so the savings from the boiler timers would be:

(1/ 3) x (230,000 kWh/ year) x 40% = **30,666 (say 31,000) kWh/year**

This would be worth:

31,000 kWh/ year x $0.031/ kWh = **$961 (say $960)/year**

The savings in the bar would be greater, as the hours the heating could be switched off would be higher.

Timers installed on the boilers would cost about $500 each. For the two boilers under consideration, the savings would be the same, for a total of about **$2,600/year of savings (or $1,920/yr if the temperature was still 23°C)**, at a cost of about $1,000.

This would give a "simple payback" of about 0.4 year, corresponding to a rate of return of 260%/ year.

E.5. Install destratification fans

The restaurant has a high ceiling, peaking at about 7 metres above the floor. This height will allow the warmest air to collect at the ceiling and not be useful for heating the floor area, where the people are. This can be remedied by installing a fan system to bring the warm air down from the ceiling to the floor: either “Casablanca” style paddle fans, or a small fan in a duct running from near the ceiling to near the floor.

The energy savings from this are difficult to calculate without knowing the extent of the temperature stratification, but in general should equate to at least a 1 C° reduction in restaurant temperature. It might be as high as more than half of the heating energy use of the restaurant, especially as the building is heated by forced air, which is normally delivered at not less than 40°C. This 40°C air would immediately rise to the top of the restaurant, and lose its heat to outside.

If the restaurant uses one-third of the heating energy of the Bloggsville Motor Inn complex, and the heat loss reduction corresponds to a 1 C° reduction in heating, for 300 days/ year, then the energy savings would be again proportional to the reduction in degree days:

300/ 2900 (degree day reduction) x 1/ 3 (of heat) x 164,250 kWh/ yr = **5,663 kWh/yr**

This would be worth:

5,663 kWh/ yr x $0.031/ kWh = **$175/year**

If, on the other hand, the savings are equal to half the restaurant heating, this is:

1/ 2 x 1/ 3 (of heat load) x 164,250 kWh/ yr = **27,375 kWh/yr**

This would be worth:

27,375 kWh/ yr x $0.031/ kWh = **$850/year**

The cost would be on the order of $500 for either two low-cost ducts with blowers or two paddle fans, giving a simple payback of between 0.6 and 2.9 years, depending on the actual savings. This corresponds to a rate of return of 35%–170%/ year.

E.6.Install insulation on ceilings

In New Zealand, only houses since 1977 have been insulated as a matter of course. Roof insulation gives a good return on investment, in terms of energy savings, though it is usually only possible where there are flat ceilings with a space below the roof for access, like at the Motor Inn.

The guest room block is about 500 square metres (17 m x 30 m), two stories high, and will have 500 square metres of roof area. The Motor Inn is heated all year round, currently to 23°C, but recommended to be heated to 20°C.

A typical room will stay about 2°C warmer than outside, due to internal heat gains[11]. Thus the annual heat loss will be the area multiplied by the annual heating degree days below 18°C, divided by the thermal insulation value (R-value). The present insulation value is 0.4.

From NZ Met Office data, the annual heating degree days at Bloggsville are 2100 °C-day/ yr, about the same as Wellington.

Thus the annual heating energy needed to make up the losses through the roof is:

(500 sq. m.) x (2100 °C-days/ year) x (24 hours/ day) / (R 0.4 sq.m. C°/ W)

= 63,000 kWh/ year

Insulation with R-2 (100 mm of fibreglass or loosefill) will reduce these losses to:

(500 sq. m.) x (2100 °C-days/ year) x (24 hours/ day) / (R 2.4 sq.m. C°/ W)

= 10,500 kWh/ year

The saving would be the difference between these two amounts, or about:

63,000 kWh/ year – 10,500 kWh/ year = **52,000 kWh/year**

At present delivered gas heat prices, this saving is worth:

(52,000 kWh/ year) x ($0.044/ kWh) = **$2,300/year**

This insulation will cost about $4/ square metre if loosefill (Insulfluff or equivalent) is used, or about $8/ square metre if fibreglass batts are used. These products are thermally identical, including the fact that loosefill will typically settle about 20% over time, and that batts may not fit tightly between ceiling joists.

Over 500 square metres, these would cost about $2000 for loosefill or $4000 for fibreglass batts, giving an averaged simple payback of 0.9 years for loosefill or 1.8 years for batts.

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[11] If we assume that each room has an average internal heat gain of 275 Watts (2 people @50 W plus 175 Watts of lights and refrigerator waste heat), and a heat loss coefficient of 138 W/ °C, the room will stay 2°C warmer than outside

2°C = 275 Watts / 138 W/ °C.

The heat loss coefficient is calculated as the sum of the individual element heat losses:

Walls	$6\ m^2 \div$ R 0.4 (m^2 °C/ W) =	= 15 W/ °C
Windows	$6\ m^2 \div$ R 0.16 (m^2 °C/ W)	= 36 W/ °C
Roof	$30\ m^2 \div$ R 0.4 (m^2 °C/ W)	= 75 W/ °C
Infiltration	72 m^3/ air change x 0.5 air changes/ hr x 0.335 W-hr/ m^3 C°	= 12 W/ °C
Total		= 138 W/ °C

E.7. Optimise boiler tune-up interval

Combustion appliances operate like automobile carburetors, and their air-fuel mixture balance shifts over time. Thus boilers, like carburetors, need tune-ups to maintain their efficiency. The optimal time period between tune-ups depends on specific circumstances, but no less than annually (at the start of the heating season) is recommended.

A specialised combustion efficiency meter is required to do this properly. A mechanical services contractor should be able to test combustion efficiency and tune the boiler for about $100.

The optimal frequency of boiler maintenance is determined by:

- measuring and recording the efficiency before tuning,
- tuning the boilers to maximum efficiency, while measuring and recording that efficiency,
- re-measuring and recording the efficiency several weeks later,
- re-tuning the boilers to maximum efficiency, while measuring and recording that efficiency.

The decline in efficiency is used to determine the next tune-up date, and the results from this are used to further optimise the tune-up interval.

The efficiency of the boilers is assumed to drop linearly over time, at a rate between 0.3%/ month and 2%/ month (a reasonable range, based on past experience). For the heat load at Bloggsville Motor Inn, a 2%/ month efficiency drop, and $100 tune-ups, the monthly cost of both boiler inefficiency and tune-ups is summed for the whole year and shown below.

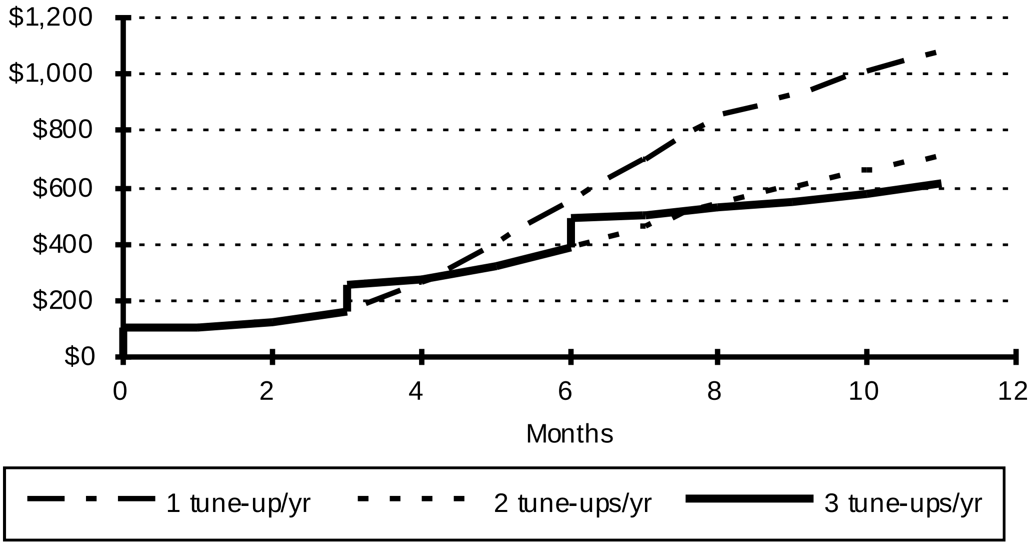

Figure A.1 - Cost optimization of furnace tune-up interval, as a function of efficiency decline

This figure shows that for boilers with this usage schedule, that fall out of tune by 2%/ month, the annual costs of a three-monthly tune-up interval are about $600. If the tune-up is done only once per year, the annual cost is $1,100. Although the two extra tune-ups cost $200, they save about $700/ yr in combustion losses. **This yields a net savings of about $500/year.**

At the other extreme, if the efficiency only dropped by 0.5%/ month, then the optimal tune-up interval is about annually. The actual decline in boiler efficiency can only be determined by measurements over a period of time.

E.8. Install insulation on boiler pipes

The boiler room has a number of uninsulated pipes and valves which are losing significant quantities of heat, wasting fuel and making the boiler room very hot and unpleasant to enter.

The largest single heat loss is from the horizontal 50 mm diameter pipe about 9 metres long, about 3 metres above floor level, which has a surface temperature of 100°C. The heat loss from this pipe to the (30°C) surroundings is calculated as:

$$q = A \times \Delta T \div R$$

$$= (\pi \times 0.05\text{ m} \times 9\text{ m}) \times (100°C – 30°C) \div (0.12\text{ m}^2\text{ C/ W})$$ [12]

$$= 800\text{ W } (0.8\text{ kW})$$

Over a year (8000 hours of operation)[13], the total heat loss is

0.8 kW x 8000 hours/ year = 6,400 kWh/ year

This is worth

6,400 kWh/ year x $0.044/ kWh = $282/ year.

There is another similar pipe leading from the boiler nearest the door to the to water header. This pipe is also 50 mm in diameter and about 2.5 metres in total length, and also has a surface temperature of 100°C. The same calculation as above shows that the heat loss from this pipe to the (30°C) surroundings is about 230 W. Over a year, the heat loss is 1,800 kWh/ year, worth about $80/ year.

The predicted savings from insulating these pipes are in proportion to the increase in thermal resistance (R-value) gained by insulating them. 25 mm thick fibreglass insulation will raise the R-value from the present R-0.12 to about R-0.6, and 50 mm of fibreglass will raise this to about R-1.1. Thus the heat loss will be reduced by about 80% with 25 mm thick insulation, and by about 90% with 50 mm thick.

Pipe insulation costs from Rawlinson's[14] are listed for pipe sizes up to 100 mm diameter. The costs vary minimally with size; as most of the cost is labour. For this estimate, we have used $14/ metre (for 25 mm diameter fibreglass covered with aluminium foil) as the costs of 50 mm diameter insulation.

At this price, the 9 metre, 50 mm diameter pipe should be able to be insulated for about $150. The heating energy saving will be about 80% of the calculated heat losses, or about **$225/year.**

Likewise, the 2.5 metre, 50 mm diameter pipe should be able to be insulated for about $50. The heating energy saving will be about 80% of the calculated heat losses, or about **$64/year**.

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12 Assuming a surface convective film resistance of 0.12, as recommended for horizontal heat loss from a surface with high emissivity at 0 m/ s air speed, in Table 6, p. 19 of New Zealand Standard NZS 4214:1977, "Methods of Determining the Total Thermal Resistance of Parts of Buildings".

13 The boilers are fired and heating is available 24 hours/ day, 7 days/ week,. The boilers are shut down for maintenance for a few weeks in January.

14 Rawlinsons New Zealand construction Handbook, 2001 edition, p. 419, from the Rawlinsons Group, P.O. Box 9804, Auckland. phone 09-524-0874, fax 09-524-4977.

E.9. Install hot water cylinder wraps

There were seven gas hot water cylinders in the facility. All the cylinders were warm (30–32°C) on their surfaces, in 23° spaces. This indicates that they are poorly insulated. All cylinders are accessible, though one is behind a locked wire fence.

As the cylinders have temperature differences between the surfaces and their surroundings of about 8 C°, and the thermal resistance of the surface air film is estimated as 0.12 m^2 C°/ W (from New Zealand Standard 4214, for a vertical surface), then with the stored water at 55°C (as measured), the temperature difference between the water and the cylinders' surfaces are about 24°C.

Assuming steady state one-dimensional heat flow, the heat flow per unit area is the same through the surface air film as it is through the tank wall. Both are in proportion to temperature difference.

Then, the heat loss (per unit area) through the surface air film is:

$$q'' (W/m^2) = \Delta T / R = (31°C - 23°C) / 0.12\ m^2\ C°/W = 66.7\ W/m^2$$

This allows us to determine the thermal resistance (R-value) between the water and the surface, as we have assumed that the heat flows are the same.

$$q'' (W/m^2) = 66.7\ W/m^2 = \Delta T / R = (55°C - 31°C) / (R_{water\text{-}surface})$$

$$\text{so, } R_{water\text{-}surface} = (55°C - 31°C) / 66.7\ W/m^2 = 0.36\ m^2\ C°/W$$

Then, the total thermal resistance of the cylinder is 0.36 + 0.12, or 0.48.

The heat loss from such a cylinder, with a surface area for heat loss of about 2.0 m^2, is:

$$(2.0\ m^2) \times (55°C - 23°C) / (0.48\ m^2\ C°/W) = 130\ Watts$$

When insulated with a 50 mm thick fibreglass (R-1) insulation blanket, its heat loss will be:

$$(2.0\ m^2) \times (55°C - 23°C) / (1.48\ m^2\ C°/W) = 43\ Watts.$$

Over a year, this saves:

(130 – 43) Watts x (8760 hr/ yr.) = **1515 kWh/year.**

Which is worth:

1515 kWh/ year x ($0.0443/ kWh) = **$67/year.**

Hot water cylinder blankets currently retail for about $60. As there are seven cylinders, with similar heat losses and savings opportunities, the total savings would be about

7 cylinders x $67/ year (per cylinder) = $470/ year.

The cost would be about $420, which would give a simple payback of about 0.9 years, or rate of return of about 110%/ year.

However, if this was done, care would need to be taken <u>not</u> to block the air draught space beneath the cylinder, as that is the combustion air supply. If the draught space is blocked, incomplete combustion and toxic fumes can result.

E.10. Install efficient shower heads

Some of the showers seemed to have high water flow rates, on the order of 12–15 litres/ minute. Flow rates this high are unnecessary to give quality showers; the important thing is to have sufficient pressure available. Water efficient shower heads maintain the pressure, while reducing the water flow rate to still acceptable levels - usually 6–8 litres/ minute.

The water savings that result from changing from a 12 Litre/ minute shower head to an 8 litre/ minute one - the most conservative savings - used ten minutes per day, 350 days per year are:

(12 – 8 L/ min.) x (10 min./ day) x (350 days/ year) = **14,000 Litres/year (or 14 m^3/yr)**

The water savings are worth, at 30¢/ m^3 of water:

14 m^3/ yr x $0.30/ m^3 = **$4.20/year (per shower head)**

The energy savings, when heating water from an average of 12°C to 45°C for the shower are:

14,000 Litres/ year x (0.00116 kWh/ L-C°) x (45°–12°C) = **536 kWh/year**

At present gas heat prices, this is worth:

(536 kWh/ year) x ($0.0443/ kWh) = **$23.70/year**

The savings would be proportionally greater if the new shower head has a flow rate under 8 litres/ minute, or the old one was higher than 12 litres/ minute, or it was used more than 10 minutes/ day.

Water efficient shower heads typically cost $25–50. At an average price of $35, each would have a "simple payback" of 1.3 years, or a rate of return of about 80%/ year.

If this is done, one of the new shower heads under consideration should be trialed in a motor inn shower first to ensure that it gives a satisfactory shower in place. Also, because each guest room viewed appeared to have a different type of shower head, the shower flow rates should be measured to ensure that the highest flow rate shower heads are the first ones to be replaced.

This can easily be done with a bucket and stopwatch. The showers that fill the bucket fastest have the highest flow rates.

E.11. Consider cold washing of bed linens

The use of colder water for washing the hotel linen would probably allow significant energy savings. 22°C water has been shown to be as effective as 70°C water in cleaning heavily soiled hospital linens, so if a cold water detergent was used, this should be sufficient for the hotel.

This would virtually eliminate the hot water requirement for the laundry, and save the **$1,600/year** of gas presently used for this.

E.12. Consider reducing excessive washing of bed linens

Some United States hotels have begun asking the guests if they want their bed linens changed every day. A large amount do not, which can lead to surprising savings, in maintenance costs as well as energy.

If washing of one-third of the bed linens can be avoided, the energy savings would amount to one-third of the laundry energy load **(about $3,400/year)**, plus reduced labour costs for washing the laundry and changing the beds, plus reduced wear and maintenance on the washers and dryers.

E.13. Consider changing dryer heat source from electricity to gas

The clothes dryers use electric heat, while most of the other heat uses in the facility use gas. If the dryers were switched from electric heated to gas heated, the savings would be in proportion to the difference in energy costs.

Expect that 95% of dryer energy use is for heating (the balance for motors). This is:

95% x 116,800 kWh/ yr = 110,960 (say 111,000) kWh/ yr

If this 111,000 kWh/ year of the laundry electricity is shifted to gas, the savings will be the difference in energy costs, plus a network charge reduction from reduced peak demand.

As most of the laundry drying is done at night, the average daily electric energy cost is taken as:

"Night" time costs "Day" time costs
(8 hr / day) x 20 kW x 2.7¢/ kWh + (16 hr / day) x 10 kW x 5.7¢/ kWh = $13.44/ day

If gas were used instead of electricity, its average daily cost would be:

320 kWh/ day x $0.0443/ kWh = $14.18/ day

And the annual energy cost savings would be:

($13.44/ day – $14.18/ day) x 365 days/ year = – **$270/year**

Also, the energy balance indicates that at peak electrical load time (early evening), the dryers contribute 20 kW to the peak demand. If they were switched to gas, the peak would drop by this amount. This would give annual network cost savings of:

20 kW x $12.08/ kVA-month x 12 months/ year = **$2,900/year**.

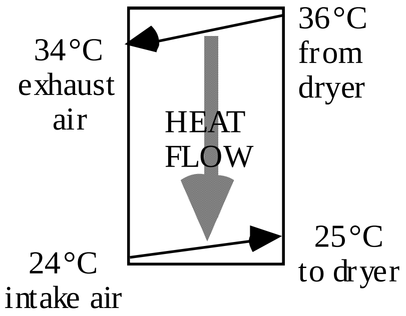
Thus the total annual energy cost savings from changing the dryers from electricity to gas would be:

– $270/ year + $2,900/ year = **$2,630/year**.

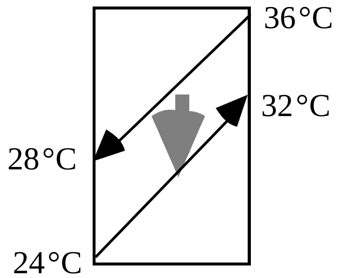
E.14. Consider heat recovery from dryer exhaust to dryer intake

The performance of the dryer heat exchanger was estimated, by measuring the inlet and outlet temperatures of both air streams through the exchanger. A heat exchanger's "effectiveness" is the ratio of the heat actually transferred to that of a perfect exchanger. For one with a balanced flow of air on both sides, the effectiveness is equal to the ratio of temperature differences, as shown in the diagram and equations below.

The small arrows represent flows of air, and their vertical height, the air's temperatures.



Actual heat exchanger
10% effective



Better heat exchanger
70% effective

In the actual heat exchanger, the effectiveness is equal to:

$$\text{Effectiveness} = \frac{\text{actual temperature change}}{\text{potential temperature change}} = \text{(in this case)} \frac{1.5\ C^\circ}{12\ C^\circ} = 13\%.$$

The better heat exchanger, as shown above, would have an effectiveness of:

$$\text{Effectiveness} = \frac{\text{actual temperature change}}{\text{potential temperature change}} = \frac{8\ C^\circ}{12\ C^\circ} = 67\%.$$

If 19 kW of the dryers 20 kW electric energy input goes into heating (the other kW into the fan and drum motors), then a 13% effective heat exchanger will provide about 2.5 kW of heat to the dryer. A 67% effective on would provide about 12 kW of heat.

The humidity of the exhaust air was not measured, and this would affect the heat exchanger sizing, as condensation can reduce the apparent effectiveness of air to air heat exchangers. Thus, based on previous experience and assumptions about the humidity of the exhaust air, a 30% effective heat exchanger may be the most practical and cost-effective size. This would provide about 6 kW of heat to the dryers.

The existing heat exchangers have an effectiveness of about 13%. Thus they will reduce the heat portion of the dryers' present 116,800 kWh/ year estimated load by about 13%. This equals:

(111,000 kWh/ year) x (13%) = 14,430 kWh/ year

At an assumed average electricity price of 6.12¢/ kWh (1.5¢/ kWh below the average total price, as half of the energy use is at night, when energy prices are down by 3¢/ kWh), this is worth:

14,430 kWh/ year x $0.0612/ kWh = $880/ yr

A 30% effective heat exchanger would provide about (30/ 13) or 2.3 times as much. This would equal

2.3 x 14,430 kWh/ year = 33,000 kWh/ year, worth about **$2,000/year**.

E.15. Consider a timer on kitchen extract fan

The kitchen stove extract fan hood (over the cooking range top) was measured as a 1 square metre exhaust port, with air flow averaging 2 m/ s. Thus the exhaust airflow was calculated as 2 m^3/ sec. The temperature of this exhaust air was measured as 35°C, about 12 C° warmer than the air inside the restaurant. The exhaust fan appeared to operate continuously, 24 hours/ day, 365 days/ year. The fan was estimated to draw 500 watts.

There is potential to eliminate this heat loss during hours when the kitchen is unused, and also to use this exhaust air source for providing some preheated ventilation air to the main building space.

If the fan could be switched off at night, when the kitchen was closed and there was no cooking, from 10 PM to 6 AM daily, there would be a significant reduction in heat loss from the building at night, from the 2 m^3/ s less air exchange.

The amount of heat exhausted was calculated as:

2 m^3/ sec. x 0.335 Wh/ m^3 C x 3600 sec/ hr x 12 °C = 29 kW.

If the Bloggsville Motor Inn needed heating for 200 nights/ year, and the kitchen exhaust heat loss could be eliminated for 8 hours/ night, then the annual heating energy savings would be:

(29 kW) x (8 hours/ day) x (200 days/ year) = **46,400 kWh/year**.

These energy savings would come at the gas end-use price. Over a year, they would be worth:

(46,400 kWh/ yr) x ($0.0443/ kWh) = **$2055/year**.

Also, the fan electrical energy savings would be:

(500 watts) x (8 hours/ day) x (365 days/ year) = **1,460 kWh/year.**

Almost all the electric energy savings would come at the lowest cost time for electricity (night), and would not affect the peak electrical demand at all. Thus the electric energy cost saving would be:

(1,460 kWh/ year) x ($0.027/ kWh) = **$39/year**.

Thus the total energy cost savings would be

$2,055/ year + $39/ year = **$2,094/year (say $2,100/yr)**

The cost to achieve this would be about $500, for a high quality seven-day timer.

E.16. Investigate heat recovery from kitchen extract air

During the time the kitchen is operating, the heat exhausted through the extract fan could be used to preheat fresh air for the building for the times when it is heated (say, 180 days/ year). If a 50% effectiveness heat exchanger were used, the energy savings would be:

(29 kW) x (16 hours/ day) x (50%) x (180 days/ year) = **42,000 kWh/year**.

Again, these energy savings would come at the gas end-use price. Over a year, they would be worth:

(42,000 kWh/ yr) x ($0.0443/ kWh) = **$1,860/year**.

The cost-effectiveness of this would depend on the cost of the heat exchanger and controls.

E.17. Keep refrigeration chiller doors closed

The heat gains to the refrigeration chillers is calculated below:

A typical walk-in chiller was about 2.4 metres high by 1.5 metres wide by 3.0 metres deep. The walls were made of 50 mm thick refrigeration paneling, at an assumed R-value of 2.0. The average cool room air temperature was 0°C; the surrounding (kitchen) air temperature was 20°C. Thus, the total cooling load due to conduction (treating floor and door like walls and roof) is:

Heat loss coefficient = A ÷ R

= 2 x {(2.4m x 3m) + (1.5m x 2.4m) + (1.5m x 3m)} ÷ R-2 (m^2 °C/ W)

= 15.3 W/ °C

At a 20°C temperature difference between the kitchen and the cool room, the conduction heat loss is:

(15.3 W/ °C) x (20°C) = 306 Watts

The average air exchange heat loss of a cooler this size is estimated as 2 air changes per hour[15]. Thus the average cooling load due to air exchange is

2 air change/ hour x (1.5m x 2.4m x 3.0m)/ air change x (0.335 W-h/ m^3 °C) = 7.2 W/ °C

At the same 20°C temperature difference, the air exchange heat loss is:

(7.2 W/ °C) x (20°C) = 144 Watts

As can be seen from Figure 11, the kitchen load is 3 kW all night. This may be assumed to be the three cool room fans operating continuously. Thus the fan load in each cool rooms is

Electrical load = 1000 Watts

If the cool room door is left open, the air exchange load is estimated as 1 air change per minute. The cooling load from this is:

1 a.c./ min. x 60 min./ hr. x (1.5m x 2.4m x 3.0m)/ a.c. x (0.335 W-h/ m^3 °C) = 217 W/ °C

At the same 20°C temperature difference, this air exchange heat loss is:

(217 W/ °C) x (20°C) = 4,300 Watts (4.3 kW)

Refrigeration coolers of this type will have a C.O.P. of about 2.0 ($kW_{thermal}$ / $kW_{electrical}$). The average cost of electric energy is about 7.62¢/ kWh. If we assume the cool room doors are left open about 2 hours/ day, then the annual cost of the energy to make up this cooling load is:

2 hr/ day x 365 days/ yr x 4.3 $kW_{thermal}$ x (1 $kW_{electrical}$ / 2 $kW_{thermal}$) x 7.62¢/ kWh

= $120/yr

This is the estimated cost of leaving the cool room doors open for 2 hours/ day.

E.18. Install timers on refrigeration units

The three beer coolers together use an average of about 3 kW (from monitoring of energy use for four days). The beer does not need to be refrigerated all night, when it is not being used, so they could be shut off for several hours each night without any loss of performance.

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15 ASHRAE Handbook of Fundamentals, 1981 edition, “Refrigeration Load” Table 4, p. 29.3, for a 10 m^3 cool storage room held at 0°C with heavy usage, American Society of Heating Refrigeration and Air Conditioning Engineers, Atlanta, Georgia, USA.

If they could be shut off for six hours per night (say 9 PM until 3 AM), then the savings would be:

3 kW x 6 hours/ night x 365 days/ year = **6,600 kWh/year.**

Because the savings would be at night, the energy cost would be lower than average, about 2.7¢/ kWh, and there would be no peak demand savings. This would translate to annual energy cost savings of:

6,600 kWh/ year x $0.027/ kWh = **$180/year**.

Perhaps the chiller run time can be reduced by even more hours, say from 9 PM until 8 AM. In this case, the savings would be even higher.

The cost of a simple 24-hour time clock would be about $150, and a more sophisticated 7-day, 24-hour about $500. A single time clock would suffice for all the beer coolers, as they are all on one circuit from the main electrical switchboard. This would give a "simple payback" of between 0.8 years and 2.8 years, or a rate of return of between 36%/ year and 120%/ year.

E.19. Investigate kitchen energy use

Energy-using equipment and practices in the kitchen weren't examined in detail, due to time and budgetary constraints of this project.

However, there may be significant scope for savings here as well, in areas such as grille and bain-marie control, dish washing temperature control, etc. The energy saving potential is probably on the order of 10% of kitchen energy use.

The total kitchen energy use is calculated as follows:

Water heating gas use	86 kWh/ day x $0.0443/ kWh x 365 days/ year = $1,390/ year
Cooking gas use	550 kWh/ day x $0.0443/ kWh x 365 days/ year = $8,900/ year
Kitchen electrical use	408 kWh/ day x $0.0762/ kWh x 365 days/ year = $11,350/ year

This totals just over $21,600/ year. A 10% saving would be worth about **$2,100/year**.

E.20. Turn off office equipment when not in use

A typical computer monitor uses about 120 watts, and the CPU and hard disk another 20 watts. If these are left on 24 hours/ day, the energy use is:

140 Watts x 24 hours/ day x 365 days/ year = 1,200 kWh/ year.

This is worth about:

1,200 kWh/ year x $0.0762/ kWh = $91.44/ year (say $90/ year).

If this can be shut off all but the eight hours a day it is in regular use, the savings are:

2/ 3 x $90/ year = **$60/year.**

Similar savings are available from shutting off the printer and photocopier in the office.

E.21. Consider a desuperheater heat recovery unit from refrigeration to hot water

A "desuperheater" is a heat recovery heat exchanger that takes some of the rejected heat from a refrigeration system and recovers it to heat water. This was considered for the Bloggsville Motor Inn, who has a large refrigeration load.

The electrical demand of the refrigeration equipment was measured by logging the current demand to the chillers at five minute intervals, as shown in Figure 11 in the main body of the report. As discussed there, the chiller demand averages 2 kW at night, and 7 kW at the other times.

The refrigeration chillers can e assumed to have a coefficient of performance (C.O.P.) of about 2.0. Thus, for an electrical demand of 7 kW, they will absorb 14 kW of heat, and reject 21 kW (the 14 kW of refrigeration load plus the 7 kW of compressor power).

A desuperheater normally recovers about 10% of the rejected heat from a refrigeration system. In this case, this would total about 2.1 kW most of the day, dropping to 0.6 kW at night. If the average is taken as 1.6 kW, over the whole year this would total

(1.6 kW) x (8760 hr/ year) = **14,000 kWh/yr**

This is a small fraction of the total water heating load of 164,000 kWh/ yr, calculated in Appendix D.

This is worth about

(14,000 kWh/ yr) x ($0.0443/ kWh) = **$620/yr**

This would also help the refrigeration equipment work slightly better, and give perhaps another $100/ year of energy savings there.

The problem with a desuperheater in this case is that there are several small chiller units, rather than a single large one. Thus, there would need to be more hardware than a single, simple unit.

The costs of this should be examined to determine if it would be cost-effective.

E.22. Install 26 mm diameter fluorescent tubes

A typical 1200 mm long, 38 mm diameter fluorescent tube uses about 40 watts. This can be reduced to about 36 watts by using the newer generation of 26 mm diameter tubes. The fluorescent ballast draws about 9 watts in either case.

The kitchen fluorescent lights are on about 16 hours/ day (6 AM–10 PM) 365 days per year. Thus the savings from switching from 38 mm diameter lamps to 26 mm diameter lamps is about:

(40 W – 36 W) x 16 hr/ day x 365 days/ year = 23 kWh/ year (per 1200 mm lamp)

At current daytime electricity prices of about 9¢/ kWh (including peak charges), this is worth:

23 kWh/ year x $0.09/ kWh = **$2/year (per 1200 mm lamp).**

This energy saving can be achieved at no cost (normally the 26 mm tubes have about a 10% lower price) by changing to 26 mm diameter tubes during normal replacement.

However, if a new 38 mm diameter lamp must be thrown away, and replaced with a ($10) 26 mm diameter lamp (if replacements are done for energy saving alone, instead of during normal maintenance), then the "Simple Payback" for this is:

Simple payback = Capital cost / Annual savings = $10 / ($2/ year) = 5 years.

Thus, this improvement is best done during regular lighting maintenance, which appears irregular at Bloggsville Motor Inn.

The energy saving are proportionally larger for larger lamps. The savings for changing an 1800 mm length 38 mm diameter lamp to a 26 mm diameter lamp are thus about:

$2/ year x (1800 mm)/ (1200 mm) = **$3/year (per 1800 mm lamp).**

There were 98 of the old style 38 mm diameter fluorescent lamps noted at Bloggsville Motor Inn during the energy audit. At an average $2/ year energy savings from each, the total annual savings from replacing them would be **$200/yr**.

The quality control problems that characterised the original batch of 26 mm tubes that was made in New Zealand in the 1980s have long ago been resolved, and all the fluorescent tubes currently sold in New Zealand are imported from Australia or Asia. However, bad memories still linger, and some facilities, to their detriment, still avoid 26 mm tubes.

E.23. Install reflectors on fluorescent lights - Restaurant kitchen

Imaging specular reflectors are a technology that uses mirrors to roughly double the light output from normal fluorescent lights.

The kitchen at Bloggsville Motor Inn contains 23 50W fluorescent lamps, in use about 16 hours/ day. Their annual energy use would be:

23 lights x 50W/ light x 16 hours/ day x 365 days/ yr = 6,700 kWh/ yr.

This is worth:

6,700 kWh/ yr x $0.09/ kWh = $600/ yr

Reflectors could save about half of this, or about **$300/yr** and maintain the same illumination. However, it would probably be more useful to maintain the energy use and double the illumination, as it is less than half the standard level for kitchens, as discussed in section 3.6.

E.24. Install compact fluorescent bulbs - Restaurant

In the restaurant, there are sixty-five 60 W light bulbs running from 6:30 AM till about 10:30 PM, 365 days a year.

The annual operating time of these bulbs is about

(16 hours/ day) x (365 days/ year) = 5840 (say 5,800) hours/ year

These bulbs have about a 1000 hour life, so they are probably replaced about every two months.

Their annual energy use is:

(60 Watts) x (5800 hours/ year) = 350 kWh/ year, per lamp

The lamps are running during the highest electricity cost times, so the annual cost is:

(350 kWh/ year) x ($0.09/ kWh) = $31.50/ year (say $32/ year) per lamp

Compact fluorescent lamps would provide as much light at about one-quarter the energy use, and with about ten times the lifetime.

The annual energy savings of a 15 Watt compact fluorescent replacing a 60 Watt bulb is:

(3/ 4) x ($32/ year) = **$24/year (per lamp).**

These also allow maintenance savings from not having to replace the bulbs as often. If these avoid the cost of six light bulbs per year, at $1 each (excluding the cost of labour), the total savings are:

$24/ year + (6 x $1) = **$30/year (per lamp).**

Thus, the total annual cost savings would be

65 lamps x $30/ year (per lamp) = **$1,950/year.**

However, these savings would be offset by some extra heating requirement. Assuming the restaurant needed heating for 200 days/ year, for the whole 16 hours/ day of operation, then the extra heat required to make up the lost heat from the more efficient lights would be:

200 days/ year x 16 hour/ day x 65 lamps x (60 – 15) W/ lamp = **9,360 kWh/yr**

The cost of gas heat to make this up would be:

9,360 kWh/ yr x $0.0443/ kWh = **$415/year**

Thus the net annual energy cost savings would be:

$1,950/ year – $415/ year = **$1,535/year**

The cost of compact fluorescents is between $25 and $50 per lamp. At an average price of $35, the total cost would be:

65 lamps x $35/ lamp = $2,300

This would yield a "simple payback" of 1.5 years, corresponding to a rate of return of 70%/ year.

Also, the restaurant would stay cooler in summer, as less cooling load would come from the lights.

E.25. Install compact fluorescent bulbs - Bar

In the Bar, there are twenty 60 W light bulbs running from about 9:30 AM till about 11:00 PM, six days a week.

The annual operating time of these bulbs is about:

(13.5 hours/ day) x (6 days/ week) x (52 weeks/ year) = 4,200 hours/ year.

These bulbs have about a 1000 hour life, so they should be replaced about every three months.

Their annual energy use is:

(60 Watts) x (4,200 hours/ year) = 253 kWh/ year, per lamp.

This costs:

(253 kWh/ year) x ($0.09/ kWh) = $22.75 / year (say $23/ year), per lamp.

Compact fluorescent lamps would provide as much light at about one-quarter the energy use, and with about ten times the lifetime.

The annual energy savings of a 15 Watt compact fluorescent replacing a 60 Watt bulb is

(3/ 4) x ($23/ year) = **$17/year (per lamp).**

These also allow maintenance savings from not having to replace the bulbs as often. If these avoid the cost of four light bulbs per year, at $1 each (excluding the cost of labour), the total savings are:

$17/ year + (4 x $1) = **$21/year (per lamp).**

Thus, the total annual cost savings would be

20 lamps x $19/ year (per lamp) = **$380/year.**

However, these savings would be offset by some extra heating requirement. Assuming the Public Bar needed heating for 150 days/ year, for 8 hours/ day (sometimes it's too warm in the pub), then the extra heat required to make up the lost heat from the more efficient lights would be:

150 days/ year x 8 hour/ day x 20 lamps x (60 – 15) W/ lamp = **1,080 kWh/yr**

The cost of gas heat to make this up would be:

1,080 kWh/ yr x $0.0443/ kWh = **$48/year**

Thus the net annual energy cost savings would be:

$380/ year – $48/ year = **$332/year (say $330/year)**

The cost of compact fluorescents is between $25 and $50 per lamp. At an average price of $35, the total cost would be:

20 lamps x $35/ lamp = $700

This would yield a "simple payback" of 2.1 years, corresponding to a rate of return of 47%/ year.

Also, the bar would stay cooler in summer, as less heat would be generated by the lights.

E.26. Install compact fluorescent bulbs - Lobby

In the lobby, there are nine R-100, 100 W reflector light bulbs running 24 hours per day.

Their annual energy use is:

(100 Watts) x (8760 hours/ year) = 876 kWh/ year, per lamp

This costs:

(876 kWh/ year) x ($0.0762/ kWh) = $67/ year, per lamp

These bulbs have about a 1000 hour life, so they are probably replaced about every one and a half months. This may involve some labour cost, due to the high ceiling in the lobby.

Compact fluorescent lamps would provide as much light at about one-quarter the energy use, and with about ten times the lifetime. However, to give the same effect, reflective compact fluorescent fixtures also need to be used.

The annual energy savings of a 28 Watt compact fluorescent lamp replacing a 100 Watt bulb is:

(72%) x ($67/ year) = **$48/year (per lamp)**

These also allow maintenance savings from not having to replace the bulbs as often. If these avoid the cost of eight reflector light bulbs per year, at $10 each (excluding the cost of labour), the total savings are:

$48/ year + (8 x $10) = **$128/year (per lamp).**

Thus, the total annual cost savings would be

9 lamps x $128/ year (per lamp) = **$1,152/year (say $1,150/year).**

The cost of compact fluorescents with reflector fixtures is about $200 per lamp. At this price , the total cost would be:

9 lamps x $200/ lamp = $1,800

This would yield a “simple payback” of 1.5 years, corresponding to a rate of return of 64%/ year.

Note: after the first year, only the bulbs will have to be changed, at a cost of about $20 each. With constant usage, they should have about a two year life.

E.27. Install compact fluorescent bulbs - Night Club

In the Night Club, there are sixty 40 W light bulbs running from 9 PM to 3 AM Thursday and Saturday, and about 4 PM - 3 AM on Friday. This equates to 23 hours/ week, plus another 7 for cleaning for a total usage of 30 hours/ week. .

The annual operating time of these bulbs is about:

(30 hours/ week) x (52 weeks/ year) = 1560 hours/ year (say 1500 hours/ year)

These bulbs have about a 1000 hour life, so they are probably replaced about every eight months.

Their annual energy use is:

(40 Watts) x (1500 hours/ year) = 60 kWh/ year, per lamp

This costs:

(60 kWh/ year) x ($0.09/ kWh) = $5.40/ year (say $5/ year), per lamp

Compact fluorescent lamps would provide as much light at about one-quarter the energy use, and with about ten times the lifetime.

The annual energy savings of a 12 Watt compact fluorescent replacing a 40 Watt bulb is:

(70%) x ($5/ year) = **$3.50/year (per lamp).**

These also allow maintenance savings from not having to replace the bulbs as often. If these avoid the cost of one and a half light bulbs per year, at $1 each (excluding the cost of labour), the total savings are:

$3.50/ year + (1.5 x $1) = **$5/year (per lamp).**

The cost of compact fluorescents is between $25 and $50 per lamp. At an average price of $35, the “simple payback” for this would be 7 years, corresponding to a rate of return of 14%/ year.

Because these lamps are used so much less than other ones at this facility, they should be low on the priority list for replacement.

E.28. Install compact fluorescent bulbs - Function room (lounge bar)

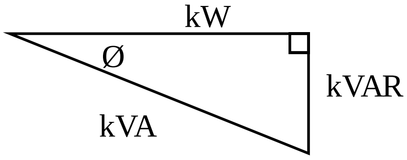
The sixty 40 W light bulbs in the function room apparently operate about the same number of hours as those in the night club, so the economics of replacing them with compact fluorescents is about the same as in the night club.

This is another low priority improvement.

E.29. Install power factor correction

BloggsPower bases their network charges on peak demands in kVA, which equal the kW of actual power demand divided by the power factor. Motors and lights cause a reduction in power factor, because of the nature of their operation. Power factor correction circuitry is often installed to bring this close to unity, so excess kVA charges can be avoided.

The effect of power factor is calculated from the "Power Triangle", as shown below.



This is a right angled triangle with kW (real power) on the horizontal axis, kVAr (reactive power) on the vertical axis, and kVA (charged power) on the hypotenuse. The angle between kW and kVA is the phase angle, Ø. The ratio of the kW to kVA is, geometrically, the cosine of the phase angle, and is called the power factor. The other elements can be determined from basic trigonometry.

In this case, we know that the peak kVA is 105 kVA, and the power factor at that point is 0.85.

Thus, peak power factor = kW / kVA = cosine Ø.

kW = kVA x cosine Ø = (105 kVA) x (0.85) = 89.3 kW.

If cosine Ø = 0.85, then Ø = arc cosine (0.85) = 31.8°

Then, kVAr = kVA x sine Ø = (105 kVA) x (sine 31.8°)

= (105 kVA) x (0.527) = 55.3 kVAr. (inductive)

If 50 kVAr (capacitive) of power factor correction is added, this will result in 5.3 kVAr (inductive).

With the same kW load, the new power factor phase angle will be

tangent Ø = kVAr / kW , or Ø = arc tangent (5.3 / 89.3) = 3.4°

So, power factor = cosine Ø = cosine (3.4°) = .998

And the resulting kVA is kVA = kW / cosine Ø = 89 kW / 0.998 = 89.2 kVA.

As kVA are charged to the nearest one, this will save (105 - 89) = 16 kVA of network charges.

The following table (taken from a spreadsheet) calculates the savings and costs from improving power factor, by using power factor correction circuitry as supplied by Metalect Industries (P.O. Box 438, Rotorua, phone 07-348-0286, fax 07-347-9707, attn. David Dawson).

kVAr added	Price	kVA svgs at peak load	Savings ($/yr)	Simple Payback (yrs.)	Resulting Power Factor (Annual peak)
30	$3,000	12	$1,629	1.84	0.9621
40	$3,250	14	$1,924	1.69	0.9856
50	$3,450	16	$2,077	1.66	0.9982
60	$3,700	16	$2,082	1.78	0.9986

According to this calculation, 50 kVAr of power factor correction would be most cost-effective, which would raise the power factor to over 0.99, at a simple payback of about 1.7 years.

E.30. Eliminate phase imbalance at switchboard

The phase voltages and currents were measured at the switchboard, and found to be slightly imbalanced (230/ 225/ 227 volts from ground). This about 2% voltage imbalance is presumably due to single-phase loads (lights, small motors) unequally loaded onto the three phases.

Ideally, phase voltages should be balanced as closely as possible. Although it is not widely appreciated, even small imbalances, caused by single phase loads being placed more on one phase than the others, can cause significant problems with three phase motors. The effect of this imbalance is difficult to quantify, but can be put into perspective by noting that a 3.5% voltage imbalance has been reported to increase motor losses by about 25%, raise motor winding temperatures by 25% (above ambient) and cut motor life in half.[16]

If we assume that the 2% voltage imbalance is typical of the wiring of the Motor Inn, that this increases motor losses by 15%, and that 5% of kitchen electrical load is affected by the imbalance, and 50% of the refrigeration chiller load, then the energy savings from remedying this are:

{(5%) x (148,920 kWh/ yr) + (50%) x (46,720 kWh/ yr)} x (15%) = 4,620 kWh/ yr

At average electric costs, this would be worth:

4,620 kWh/ yr x $0.0762/ kWh = **$350/yr**

It is recommended to monitor the voltages and currents on each phase of the main electrical supply for about a week, to see how regular the imbalance is. If the imbalance is regular, balance the single-phase loads on each electrical phase, for example by switching some lights from the red to the blue phase, until the current draws and voltages again balance closely.

16 Drivepower Technology Atlas, August 1993, p. 255 and 277, published by E SOURCE INC., 1050 Walnut Street, Boulder CO USA 80302.

E.31. Install efficient urinal flow sensors (Water savings)

Automatic flushing urinals are known to use 2 – 20 cubic metres of water per day.

The one urinal that was measured at Bloggsville Motor Inn had a 20 litre cistern, which flushed automatically every 6 minutes. This uses:

20 Litres/ 6 minutes x 60 minutes/ hour x 24 hours/ day x (m^3/ 1000 Litre) = 4.80 m^3/ day

Continuous flushing urinals use about four times this much, or about 20 m^3/ day.

If each urinal at the Bloggsville Motor Inn is estimated to use 5 m^3/ day, and at least 80% of this can be saved by using an automatic flushing valve(so the urinal is only flushed when necessary, not continuously), so the water savings from this are:

80% savings x 5 m^3/ day x 365 days/ year = **1,460 m^3/year**

At 30¢/ m^3 for water, this is worth:

1,460 m^3/ year x 30¢/ m^3 = **$438/year (say $440/year)**

The automatic cistern controllers range from about $550 to $800 each, installed. Thus, they give simple paybacks of 1.2 to 1.8 years and annual rates of return of 55%/ year to 83%/ year.