VLA Test Memo # 223

# VLA Energy Survey 1999

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November 30,1999

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**Abstract**
Power consumption at the Very Large Array (VLA) has been monitored for several years. As operating costs continue to rise, energy conservation can play an important role in running the facility more efficiently.

Several events since 1988 have reduced power consumption at the site. The most significant has been the installation of Direct Digital Controllers (DDC) on the antennas. This modification has reduced our annual power consumption by 1,000,000 kilowatt hours. A history of VLA power consumption and major events are plotted in section 2.01.

Monitoring power consumption at all the site transformers helps to identify the major use areas. Surveys were performed in 1986 and 1999. The survey results are tabulated in section 2.02.

Upgrading old equipment offers power savings in many areas. Upgrading the site chillers can reduce power consumption by 157,000 kilowatt hours annually. Changing out old wall air conditioning units will reduce consumption by an additional 40,000 kilowatt hours. Payback periods for both of these items are less then 4 years. Other initial projects are recommended in section 4.00. The total estimated annual savings for the projects listed would be $22,000 and our annual power consumption would be reduced by 363,000 kilowatt hours (3.5% of present consumption).

Budgeting for Energy related projects should be encouraged and reviewed on a regular basis. The cost per kilowatt-hour is on the rise once again.

## 1.00 Discussion And Scope

This energy survey focuses on developing a list of areas and items to address in the coming years and budgets. Projects will be initiated to investigate cost and payback.

There are energy savings available by simply upgrading older and inefficient equipment. Equipment upgrades and replacement should be a part of future budgets. With some equipment it makes sense to wait until the piece fails or the next major overhaul. With others as the analyses might show it makes good sense to replace the equipment immediately.

As an example: The chillers are 25 years old and the cost to rebuild a chiller compressor is greater then 50 percent of the cost of a new chiller. When the next compressor is due to be rebuilt a chiller should be replaced. The newer units will reduce power consumption by 157,000 KWH per year.

Electricity saved now is also saved every year into the future.

**2.00 VLA Energy History**
Even with the efforts to reduce power consumption the overall cost is starting to rise once again. While site consumption has decreased our electric bill has increased.

| Year | Energy KWH Consumption | Electric Bill | Cost/KWH |
|---|---|---|---|
| 1986 | 10821000 | $800,485 | $0.0740 |
| 1994 | 9854400 | $495,074 | $0.0502 |
| 1998 | 9038400 | $569,877 | $0.0632 |
| 1998 Generated | 189000 | $15,000 | $0.0790 |

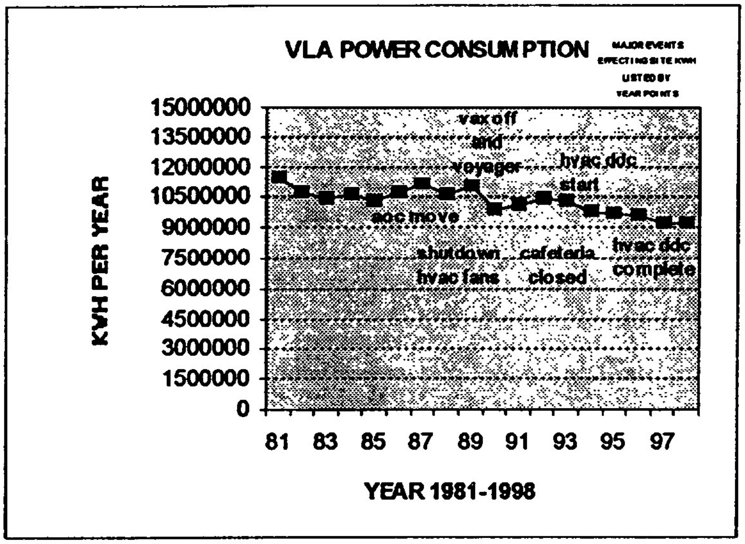
The VLA has two 1500kw Caterpiller generator sets, left from the Voyager Project. During 1989 to 1993 a decision was made to generate our own site power. The intent was to generate power cheaper than we could buy it for from Socorro Electric Cooperative (SEC). Negotiations with SEC lead us to try a few different operating schedules with different load shedding options. Eventually we started generating full time. Toward the end of 1993 a rate was negotiated with SEC and we started purchasing power once again. These rate negotiations with Socorro Electric Cooperative contributed to reducing the VLA electric bill substantially.

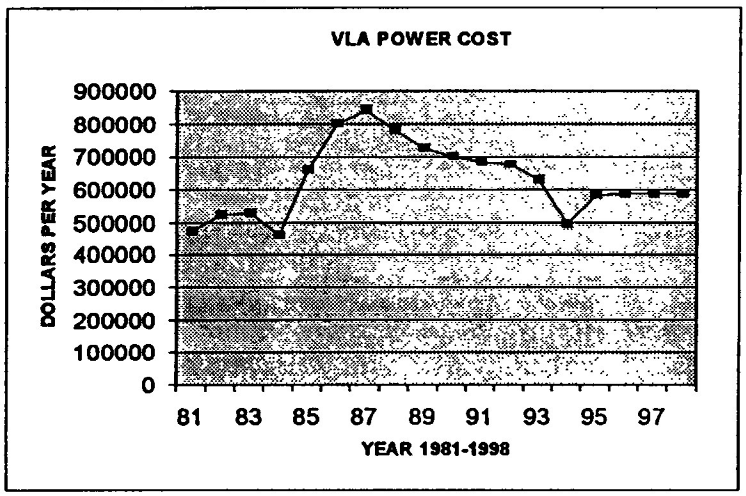
During 1993-1997 the VLA antennas were retrofitted with DDC controls on the Vertex Room air conditioning. This upgrade has reduced site kilowatt hour consumption by 8-10% or one million kilowatt hours per year. At today's cost this KWH reduction translates into an estimated $70,000 saved annually. An additional $7200 in demand charges are also saved.

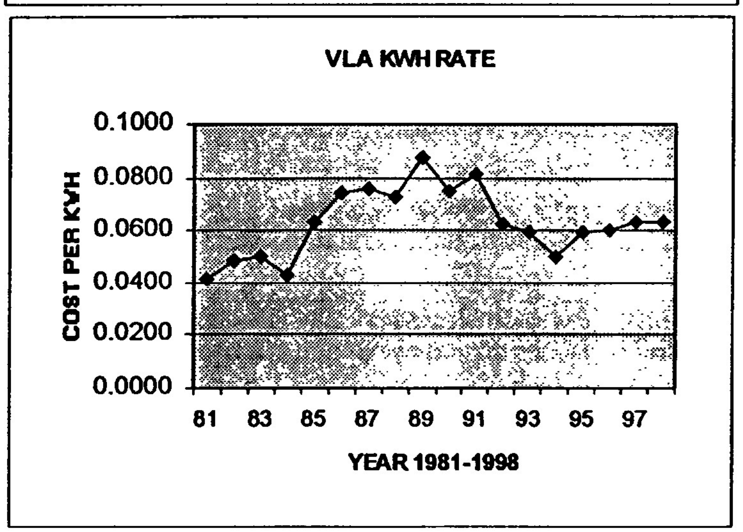
**2.01 Major Events**
From 1988 to 1997 there were several events that reduced KWH consumption at the site: Site power consumption is plotted from 1981 through 1998 with the events noted on the graph during the year they took place. A plot of yearly power cost is also given.

Events:
a. Move to Array Operations Center (AOC) - November of 1988
b. Relocate Vax to AOC - November of 1988
c. Voyager- August of 1989
d. The installation of DDC Controls on the VLA antenna vertex room heating and air conditioning system – November 1993 to October 1997
e. Control Building HVAC system building and computer fans were turned off about1990/1991.
f. Cafeteria was shutdown – February of 1993.

## VLA Power Consumption And Power Cost From 1981 Through 1998



**2.02 Monitoring Power Consumption 1986 and 1999**
In August of 1986 a partial power consumption breakdown were gathered. A power monitor was placed at different transformers to collect usage data. Collections points included the main transformers at the Control Building, Cafeteria, Antenna Barn, Vax/Slob, Technical Services area and one Antenna.

In September of 1999 we also collected usage data to compare the different areas. We will monitor the same transformers in January 2000 to check the winter loading. The table below compares the surveys in the summers of 1986 and 1999.

**Power Monitoring 1986 and 1999**

| | Ranges | Ranges |
|---|---|---|
| Site Area | August, 1986 | September, 1999 |
| | Kilowatts | Kilowatts |
| Antenna | 18.3 | 19.25 |
| (19kw/antenna * 27) | 494 | 519.75 |
| Control Building | 385 | 295 |
| MD Panel | 68.8 | 89.05 |
| Cafeteria Building | 22.09 | 10.72 |
| Antenna Building | 16.24 | 37.27 |
| Vax/Slob | 45.26 | 2.2 |

The comparison shows that our two main consumers of energy are the Antennas and the Control Building. It also shows that in some areas consumption has increased.

**3.00 Listing of Energy Items To Review**
The listing will be maintained and updated yearly. Projects will be discussed with management and assigned as the budget allows.

**3.01 Upgrade Equipment**
A) Possible alternates for Heating, Ventilating and Air Conditioning (HVAC) equipment.
1. Technical Services HVAC wall units: Install heat pump wall unit.
2. Cryogenics at Tech Services: Install split system heat pump unit.
3. Antenna Barn: Replace furnace in the VLBA Shop Area.
4. Antenna Barn: Install heat pump wall unit.
5. Warehouse offices HVAC: Install heat pump wall unit.
6. Servo HVAC: Install heat pump wall unit.
7. Cafeteria Heat Pumps: Install newer heat pumps.
8. Visitor Sleeping Quarters: Install heat pump wall units.
9. Control Building: Install new Chillers.

B) Energy efficient motors where justified.
C) Cafeteria: Install a second smaller hot water heater. In progress.
D) Variable Frequency Drives (where applicable).

E) Soft Starts (where applicable).
F) Capacitors to improve power factor (if we pay for low power factor).

**3.02 Lighting**
A) Review all lighting and replace with energy efficient lights and ballasts.
Use lower wattage light bulbs where possible.
B) Low pressure sodium or LED instead of incandescent.
C) Turn off light stickers.
D) Motion sensors- Identify locations inside and outside of buildings.
E) Skylights.

**3.03 Operation (buildings/antennas)**
A) Antennas
1. Can some of the equipment be turned off? Pedestal Room air conditioning?
2. Azimuth and Elevation Gearbox Fans. Investigate the need for fans. The cost to operate drive fans is $40,000 a year.
3. Reduce or widen set point temperature range in Pedestal room.
4. Stagger antennas during slew can reduce demand?
5. Feed heaters: Presently all the heaters come on at one time. Redesign for individual switching or automate using weather data.
6. Insulate upper pedestal. Cover openings to yoke.
7. Insulate vertex room.
8. Brushless DC drives for the antennas (manhour maintenance savings).

B) Use swamp coolers for cooling in place of wall units (in progress).
C) Investigate chilled water requirements.
D) Do we need the computer air system any longer?
E) Install enthalpy controller on building system. Controller is already in hand.
F) Reduce seal water usage at Cooling Tower Sump Pump.

**3.04 Buildings**
A) Insulated windows.
B) Control building boiler for humidity control. Is humidity control required any longer?
C) Waste oil heater mechanics area.
D) Warehouse add ceiling fans min (4)- personnel comfort and mixing.

**3.05 Other**
A) Solar Panels (are still too expensive)

## 4.00 Payback Analyses Table

Payback Analyses use the simple payback method. Projects taken from sections 3.01A (1-6), 3.01B, 3.02A, and 3.04C.

| | Payback Table | Kilowatt-Hours | LPG Saved | Equipment | **Energy Savings | Payback |
|---|---|---|---|---|---|---|
| | Payback Analyses | Saved Annually | Annually | Cost | Annually | Years |
| 1 | Control Building Chillers | | | | | |
| | Replace one Chiller | 157000 | | $38,000 | $10,000 | 3.8 |
| | *Replace two Chillers | 157000 | | $76,000 | $10,000 | 7.6 |
| 2 | Wall Air Conditioning Units | | | | | |
| | For ten units | 42000 | | $8,000 | $2,600 | 3.1 |
| 3 | Lighting Ballasts Replacement | | | | | |
| | Four bulb ballast (200) | 32000 | | $6,000 | $2,000 | 3 |
| | Two bulb ballast (390) | 17846 | | $7,800 | $1,124 | 6.94 |
| 4 | Energy Efficient Motors (HVAC System) mfg claims 3%-5% savings/yr | | | | | |
| | 6-15hp motors @4%/yr | 29500 | | $3,000 | $1,854 | 1.7 |
| 5 | Antenna Barn Furnace | | | | | |
| | Est. 10% savings new unit | | 276Gal. LPG | $800 | $276 | ~3 |
| 6 | Waste Oil Heater | | | | | |
| | If only 500 gallons of waste | | | | | |
| | available. Supplement with #2 diesel | 50000 | | $6,000 | $2,000 | 3 |
| 7 | Cryogenics Area Air Conditioning | | | | | |
| | New Split System Heat Pump | 34900 | | $5,000 | $2,200 | 2.2 |
| | | | | | | |
| | Overall (with one chiller) | 363246 | | $74,600 | $22,054 | 3.38 |
| | Overall (with two chiller) | 363246 | | $112,600 | $22,054 | 5.11 |
| | | | | | | |
| | * Presently we only operate one chiller. | | | | | |
| | Cost to rebuild a compressor is >50% of the cost of a new chiller. | | | | | |
| | **Energy savings based on a 90 day heating season and a 120 day cooling season. | | | | | |

## 5.00 Recommendations

This survey is a only a guide. Each of the areas listed should be reviewed closely and where there is a potential for reducing consumption a payback analysis should be completed. The method of analysis can be reviewed by the Business Division.

More important is that NRAO develop an energy budget. Whenever an energy project passes the payback criteria it should be implemented in some reasonable time frame.

The seven projects listed in section 4.00 should be completed. Other projects in section 3.00 such as Brushless DC Motors, Antenna Drive Motor Fan circuitry (which will reduce fan usage), Feed Heaters, Enthalpy Controllers should be reviewed. If the payback criteria is met they should be submitted for approval.

For general information a list of ways to reduce utility costs are included in Appendix A.

# Appendix A

250+ Ways To Reduce Industrial Utility Costs (Mears, 1999)

Blowers (also see "Motors")

- Locate air intakes to obtain appropriate air quality and best efficiency.
- Use smooth, well-rounded air inlet ducts or cones for air intakes.
- Minimize blower inlet and outlet obstructions.
- Clean screens and filters regularly.
- Use backward-inclined blower wheel designs.
- Minimize blower speed.
- Consider using a two-speed motor and running at the low speed whenever possible.
- Use low-slip or no-slip belts.
- Check belt tension regularly.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable blower loads.
- Use energy-efficient motors for continuous or near-continuous operation. Related article.
- Use properly-sized ductwork with appropriate bends and transitions.
- Eliminate ductwork leaks.
- Turn blowers off when they are not needed.

Buildings (also see "HVAC")

- Seal exterior cracks/openings/gaps with caulk, gasketing, weatherstripping, etc.
- Consider new thermal doors, thermal windows, roofing insulation, etc.
- Install windbreaks near exterior doors.
- Replace single-pane glass with insulating glass.
- Consider covering some window and skylight areas with insulated wall panels inside the building.
- If visibility is not required but light is required, consider replacing exterior windows with insulated glass block.
- Consider tinted glass, reflective glass, coatings, awnings, overhangs, draperies, blinds, and shades for sunlit exterior windows.
- Use landscaping to advantage.
- Add vestibules or revolving doors to primary exterior personnel doors.
- Consider automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
- Use intermediate doors in stairways and vertical passages to minimize building stack effect.
- Use dock seals at shipping and receiving doors.
- Bring cleaning personnel in during the working day or as soon after as possible to minimize lighting and HVAC costs.

Chillers (also see "Refrigeration" and "Cooling Towers")

- Increase the chilled water temperature set point if possible.

• Use the lowest temperature condenser water available that the chiller can handle.
• Clean heat exchangers when fouled.
• Optimize condenser water flow rate and refrigerated water flow rate.
• Replace old chillers or compressors with new higher-efficiency models. Related article.
• Use water-cooled rather than air-cooled chiller condensers.
• Use energy-efficient motors for continuous or near-continuous operation. Related article.
• Specify appropriate fouling factors for condensers.
• Use the most efficient refrigerant.
• Do not overcharge refrigerant.
• Do not overcharge oil.
• Install a control system to coordinate multiple chillers.
• Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple chillers.
• Run the chillers with the lowest operating costs to serve base load.
• Avoid oversizing -- match the connected load.
• Isolate off-line chillers and cooling towers.
• Establish a chiller efficiency-maintenance program.

Compressed air (also see "Compressors" and related article)
• Install a control system to coordinate multiple air compressors.
• Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple air compressors.
• Avoid oversizing -- match the connected load.
• Load up modulation-controlled air compressors. (They use almost as much power at partial load as at full load.)
• Turn off the back-up air compressor until it is needed.
• Reduce air compressor discharge pressure to the lowest acceptable setting. (This will reduce compression energy requirements and compressed air leakage rates.)
• Use the highest reasonable dryer dew point settings.
• Turn off refrigerated and heated air dryers when the air compressors are off.
• Use a control system to minimize heatless desiccant dryer purging.
• Minimize purges, leaks, excessive pressure drops, and condensation accumulation.
• Use drain controls instead of continuous air bleeds through the drains.
• Consider engine-driven or steam-driven air compression to reduce electrical demand charges.
• Change the electric motors to an energy-efficient designs. Related article.
• Replace standard v-belts with high-efficiency cogged v-belts as the old v-belts wear out.
• Use a small air compressor for HVAC load when production load is off.
• Take air compressor intake air from the coolest (but not air conditioned) location.
• Use an air-cooled aftercooler to heat building makeup air in winter.

• Be sure that heat exchangers are not fouled (e.g. -- with oil).
• Be sure that air/oil separators are not fouled.
• Monitor pressure drops across suction and discharge filters and clean or replace filters promptly upon alarm.
• Use a properly sized compressed air storage receiver.
• Minimize disposal costs by using lubricant that is fully demulsible and an effective oil-water separator.
• Consider alternatives to compressed air such as blowers for cooling, hydraulic rather than air cylinders, electric rather than air actuators, and electronic rather than pneumatic controls.
• Use nozzles or venturi-type devices rather than blowing with open compressed air lines.
• Check for leaking drain valves on compressed air filter/regulator sets. Certain rubber-type valves may leak continuously after they age and crack.
• In dusty environments, control packaging lines with high-intensity photocell units instead of standard units with continuous air purging of lenses and reflectors.
• Establish a compressed air efficiency-maintenance program.

Compressors
• Consider variable speed drive for variable load on positive displacement compressors.
• Use a synthetic lubricant if the compressor manufacturer permits it.
• Be sure lubricating oil temperature is not too high (oil degradation and lowered viscosity) and not too low (condensation contamination).
• Change the oil filter regularly.
• Periodically inspect compressor intercoolers for proper functioning.
• Use waste heat from a very large compressor to power an absorption chiller or preheat process or utility feeds.
• Establish a compressor efficiency-maintenance program.

Condensate
• Return steam condensate to boiler feedwater where the return system cost is justified.
• Inspect steam traps regularly.
• Use HVAC condensate to avoid make-up water and sewer costs (e.g. -- use HVAC condensate for cooling tower make-up water).

Cooling towers
• Control cooling tower fans based on leaving water temperatures.
• Control to the optimum water temperature as determined from cooling tower and chiller performance data.
• Use two-speed or variable-speed drives for cooling tower fan control if the fans are few. Stage the cooling tower fans with on-off control if there are many.
• Turn off unnecessary cooling tower fans when loads are reduced.
• Cover hot water basins (to minimize algae growth that contributes to fouling).

- Balance flow to cooling tower hot water basins.
- Periodically clean plugged cooling tower water distribution nozzles.
- Install new nozzles to obtain a more-uniform water pattern.
- Replace splash bars with self-extinguishing PVC cellular-film fill.
- On old counterflow cooling towers, replace old spray-type nozzles with new square-spray ABS practically-non-clogging nozzles.
- Replace slat-type drift eliminators with high-efficiency, low-pressure-drop, self-extinguishing, PVC cellular units.
- If possible, follow manufacturer's recommended clearances around cooling towers and relocate or modify structures, signs, fences, dumpsters, etc. that interfere with air intake or exhaust.
- Optimize cooling tower fan blade angle on a seasonal and/or load basis.
- Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
- Use a velocity pressure recovery fan ring.
- Divert clean air-conditioned building exhaust to the cooling tower during hot weather.
- Re-line leaking cooling tower cold water basins.
- Check water overflow pipes for proper operating level.
- Optimize chemical use.
- Consider side stream water treatment.
- Restrict flows through large loads to design values.
- Shut off loads that are not in service.
- Locate make-up and blowdown tie-ins to minimize heat tracing cost in winter.
- Take blowdown water from the return water header.
- Optimize blowdown flow rate.
- Automate blowdown to minimize it.
- Send blowdown to other uses or to the cheapest available sewer allowed. (Remember, the blowdown does not have to be removed at the cooling tower. It can be removed anywhere in the piping system.)
- Implement a cooling tower winterization plan to minimize ice build-up.
- Avoid simultaneous water heating and cooling in cold weather.
- Install interlocks to prevent fan operation when there is no water flow.
- Establish a cooling tower efficiency-maintenance program.

Drives (also see "Motors")

- Use variable-speed drives for large variable loads. (Remember that engines can be variable-speed too.)
- Use high-efficiency gear sets.
- Use precision alignment.
- Check belt tension regularly.
- Eliminate variable-pitch pulleys.
- Use synchronous belts as no-slip alternatives to v-belts.
- Use synthetic lubricants for large gearboxes.
- Eliminate eddy current couplings.

• When they're not needed, shut them off.

Electricity (also see "Lighting" and "Motors")

• Shop for best price in the deregulated electricity market. Related article.
• Know your historical demand profile so you can make the best deal in the deregulated electricity market.
• If your load factor is poor, aggregate with other sites that have higher load factors so you can make the best deal in the deregulated electricity market.
• Shift loads to off-peak times if possible.
• Know the cost of setting a new electric peak demand and set alarms and shut down equipment accordingly.
• Stagger start-up times for equipment with large starting currents to minimize load peaking.
• Use standby electric generation equipment for on-peak high load periods.
• Test emergency generators during on-peak high load periods.
• Delay start-up of new equipment to prevent a new summer peak.
• If possible, shut off a piece of equipment before starting the alternate piece.
• Consider alternative electric rate schedules (e.g. -- interruptible rate).
• Take advantage of utility rebate programs (e.g. -- lighting upgrade, thermal storage, energy efficient motors).
• Correct power factor to at least 90% under rated load conditions.
• Buy the substation, transformer, etc. from the utility.
• Relocate transformers close to main loads.
• Set transformer taps to optimum settings.
• Disconnect primary power to transformers that do not serve any active loads (e.g. -- seasonal loads or surplused transformers).
• Consider on-site electric generation or cogeneration.
• Have the utility "buy out" your cogeneration plan (i.e. -- reduce your rate if you will terminate the project).
• Check electric meter printouts and electric bills for use during outages and holiday shut-down periods. (You'd be amazed at the true stories that can be told. Clerks sometimes fill in gaps!)
• Shut off unnecessary computers, printers, and copiers at night.
• Buy Energy Star compliant products.

Fans (also see "Motors")

• Use smooth, well-rounded air inlet cones for fan air intakes.
• Avoid poor flow distribution at the fan inlet.
• Minimize fan inlet and outlet obstructions.
• Clean screens, filters, and fan blades regularly.
• Use airfoil-shaped fan blades.
• Minimize fan speed.
• Consider using a two-speed motor and running at the low speed whenever possible.
• Use low-slip or no-slip belts.

• Check belt tension regularly.

• Eliminate variable pitch pulleys.
• Use variable speed drives for large variable fan loads.
• Use energy-efficient motors for continuous or near-continuous operation. Related article.
• Use properly-sized ductwork with appropriate bends and transitions.
• Eliminate ductwork leaks.
• Turn fans off when they are not needed.

Fire protection systems
• Test electric fire pumps during electrical off-peak periods.
• Automate pressure maintenance pumps to only run when water pressure is low.
• Check for continuous overflow at storage tank due to an open feed.
• Check water overflow pipes for proper operating level.
• Consider using the storage tank for refrigerated water thermal storage.

Heat exchangers
• Specify appropriate heat exchanger fouling factors.
• Maintain "self-cleaning" fluid velocities.
• Clean heat exchangers when excessively fouled.
• Turn off the flow when the heat exchanger is out of service.
• Routinely log process data for assessment of fouling and establish a heat exchanger efficiency-maintenance program.

HVAC (Heating / Ventilation / Air Conditioning) (also see "Blowers" and "Buildings" and "Chillers" and "Cooling towers" and "Fans")
• Tune up the HVAC control system.
• Consider installing a building automation system (BAS) or energy management system (EMS) or restoring an out-of-service one.
• Balance the system to minimize flows and reduce blower/fan/pump power requirements.
• Eliminate or reduce reheat whenever possible.
• Prevent unauthorized thermostat adjustments.
• Use appropriate HVAC thermostat setback.
• Raise "cool" settings and lower "heat" settings to appropriate levels.
• Use morning pre-cooling in summer and pre-heating in winter (i.e. -- before electrical peak hours).
• Use building thermal lag to minimize HVAC equipment operating time.
• In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials.
• In summer during unoccupied periods, allow temperatures to rise as high as possible without damaging stored materials.
• Improve control and utilization of outside air.

• Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.
• Reduce HVAC system operating hours (e.g. -- night, weekend).
• Optimize ventilation.
• Ventilate only when necessary. To allow some areas to be shut down when unoccupied, install dedicated HVAC systems on continuous loads (e.g. -- computer rooms).
• Provide dedicated outside air supply to kitchens, cleaning rooms, combustion equipment, etc. to avoid excessive exhausting of conditioned air.
• Use evaporative cooling in dry climates.
• Reduce humidification or dehumidification during unoccupied periods.
• Use atomization rather than steam for humidification where possible.
• Clean HVAC unit coils periodically and comb mashed fins.
• Upgrade filter banks to reduce pressure drop and thus lower fan power requirements.
• Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate.
• Check pneumatic controls air compressors for proper operation, cycling, and maintenance.
• Isolate air conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains.
• Install ceiling fans to minimize thermal stratification in high-bay areas.
• Relocate air diffusers to optimum heights in areas with high ceilings.
• Consider reducing ceiling heights.
• Eliminate obstructions in front of radiators, baseboard heaters, etc.
• Check reflectors on infrared heaters for cleanliness and proper beam direction.
• Use professionally-designed industrial ventilation hoods for dust and vapor control.
• Use local infrared heat for personnel rather than heating the entire area.
• Use spot cooling and heating (e.g. -- use ceiling fans for personnel rather than cooling the entire area).
• Purchase only high-efficiency models for HVAC window units.
• Put HVAC window units on timer control.
• Improve crude temperature control of multiple HVAC window units.
• Control infrared heaters based on ambient temperature.
• Don't oversize cooling units. (Oversized units will "short cycle" which results in poor humidity control.)
• Use a system of multiple modular boilers instead of one large boiler.
• Install multi-fueling capability and run with the cheapest fuel available at the time.
• Consider dedicated make-up air for exhaust hoods. (Why exhaust the air conditioning or heat if you don't need to?)
• Minimize HVAC fan speeds.
• Consider desiccant drying of outside air to reduce cooling requirements in humid climates.
• Consider ground source heat pumps.
• Seal leaky HVAC ductwork.
• Seal all leaks around coils.
• Repair loose or damaged flexible connections.

• Eliminate simultaneous heating and cooling during seasonal transition periods.
• Consider directing clean conditioned exhaust air to the inlet of a cooling tower, air-cooled condenser, or evaporative cooler when doing so will reduce energy requirements.
• Zone HVAC air and water systems to minimize energy use.
• Inspect, clean, lubricate, and adjust damper blades and linkages.
• Establish an HVAC efficiency-maintenance program.

Insulation

• Repair damaged insulation.
• Insulate any hot or cold metal or insulation.
• Replace wet insulation.
• Use an infrared gun to check for cold wall areas during cold weather or hot wall areas during hot weather.
• Consider adding insulation to water heaters, etc. located in unheated/uncooled spaces.
• Insulate HVAC ducts running outside and through unoccupied spaces.
• Take vapor barriers and insulation coverings very seriously.

Lighting (also see "Electricity")

• Reduce excessive illumination levels to standard levels using switching, delamping, etc. (Know the electrical effects before doing delamping.)
• Aggressively control lighting with clock timers, delay timers, photocells, and/or occupancy sensors.
• Install efficient alternatives to incandescent lighting, mercury vapor lighting, etc. Efficiency (lumens/watt) of various technologies range from best to worst approximately as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, mercury vapor, incandescent.
• Select ballasts and lamps carefully with high power factor and long-term efficiency in mind.
• Upgrade obsolete fluorescent systems to T-8 lamps and electronic ballasts. Related article.
• Consider T-5 fluorescent lighting systems for new construction.
• Consider lowering the fixtures to enable using less of them.
• Consider painting the walls a lighter color and using less lighting fixtures or lower wattages.
• Use task lighting and reduce background illumination.
• Re-evaluate exterior lighting strategy, type, and control. Control it aggressively.
• Change exit signs from incandescent to LED.

Miscellaneous

• Meter any unmetered utilities. Know what is normal efficient use. Track down causes of deviations.
• Shut down spare, idling, or unneeded equipment.
• Make sure that all of the utilities to "mothballed" areas are turned off -- including utilities like compressed air and cooling water.
• Install automatic control to efficiently coordinate multiple air compressors, chillers, cooling tower cells, boilers, etc.

• Renegotiate utilities contracts to reflect current loads and variations.
• Consider buying utilities from neighbors, particularly to handle peaks.
• Leased space often has low-bid inefficient equipment. Consider upgrades if your lease will continue for five or more years.
• Take as much of the sales tax exclusion on manufacturing utilities as you can take.
• Avoid late payment charges.
• Use alternative sampling systems to eliminate sample hoods, thus reducing water, sewer, and ventilation requirements.
• Stop using rental equipment for long-term requirements. Install permanent high-efficiency equipment where appropriate.
• Adjust fluid temperatures within acceptable limits to minimize undesirable heat transfer in long pipelines.
• Minimize use of flow bypasses and minimize bypass flow rates.
• Provide restriction orifices in purges (nitrogen, steam, etc.).
• Eliminate unnecessary flow measurement orifices.
• Consider alternatives to high pressure drops across valves.
• Turn off winter heat tracing that is on in summer.

Motors (also see "Drives" and "Electricity")
• Properly size to the load for optimum efficiency.
• Use energy-efficient motors where economical. Related article.
• Use synchronous motors to improve power factor.
• Check alignment.
• Check for under-voltage and over-voltage conditions.
• Balance the three-phase power supply.
• Require efficiency restoration from motor rewinding.

Nitrogen & other specialty gases
• Shop for best specialty gas prices.
• Generate nitrogen or oxygen with a membrane system where lower quality than cryogenic will suffice.
• Use liquid nitrogen vaporization for cooling.
• Use liquid nitrogen vaporization for vent stream VOC condensation.
• Periodically survey gas systems (especially oxygen, nitrogen, and other high cost gases) using ultrasonic and other leak detection methods and fix leaks.

Pumping (also see "Motors" and "Water & sewer")
• Operate pumping near best efficiency point.
• Modify pumping to minimize throttling.
• Adapt to wide load variation with variable speed drives or sequenced control of smaller units.
• Stop running both pumps -- add an auto-start for an on-line spare or add a booster pump in a problem area.
• Use booster pumps for small loads requiring higher pressures.

- Increase fluid temperature differentials to reduce pumping rates.
- Repair seals and packing to minimize water waste.
- Balance the system to minimize flows and reduce pump power requirements.
- Use siphon effect to advantage: don't waste pumping head with a free-fall return.

Refrigeration (also see "Chillers" and "Cooling towers" and "HVAC")

- Use water-cooled condensers rather than air-cooled condensers.
- Challenge the need for refrigeration, particularly for old batch processes.
- Avoid over sizing -- match the connected load.
- Consider gas-powered refrigeration equipment to minimize electrical demand charges.
- Use "free cooling" to allow chiller shutdown in cold weather.
- Use refrigerated water loads in series if possible.
- Convert firewater or other tanks to thermal storage.
- Don't assume that the old way is still the best -- particularly for energy-intensive low temperature systems.
- Correct inappropriate brine or glycol concentration that adversely affects heat transfer and/or pumping energy.
- If it sweats, insulate it. If it is corroding, replace it first. (Want to hear a sad story about how a large amount of refrigerant was lost for ignoring this one?)
- Consider adding hot gas bypass if it will reduce power consumption.
- Make adjustments to minimize hot gas bypass operation.
- Insulate hot gas lines that are inside buildings.
- Inspect moisture/liquid indicators.
- Consider change of refrigerant type if it will improve efficiency.
- Check for correct refrigerant charge level.
- Inspect the purge for air and water leaks.
- Establish a refrigeration efficiency-maintenance program.

Steam (also see "Boilers")

- Fix steam leaks and condensate leaks.
- Accumulate work orders for repair of steam leaks that can't be fixed during the heating season due to system shutdown requirements. Tag each such leak with a durable tag with a good description.
- Use let-down steam turbines to produce lower steam pressures.
- Use more-efficient steam desuperheating methods.
- Inspect steam traps regularly and repair malfunctioning traps promptly.
- Challenge orifice traps.
- Consider recovery of vent steam (e.g. -- on large flash tanks).
- Use waste steam for water heating.
- Use an absorption chiller to condense exhaust steam before returning the condensate to the boiler.
- Use electric pumps instead of steam eductors for sump clean-out, or at least provide reliable automatic shut-off.

- Establish a steam efficiency-maintenance program.

Steam turbines (also see "Boilers" and "Steam")
- Re-evaluate options if efficiency is less than 65% (e.g. -- avoid small crude steam turbines).
- Use steam turbines for large volume pressure letdown.
- Use a piggy-back absorption system where existing chillers are driven by steam turbines.
- Establish a steam turbine efficiency-maintenance program.

Waste recovery
- Recover heat from flue gas, engine cooling water, engine exhaust, low pressure waste steam, drying oven exhaust, boiler blowdown, etc.
- Recover fuel from vent streams.
- Recover heat from thermal oxidizer or incinerator off-gas.
- Use waste heat for fuel oil heating, boiler feedwater heating, outside air heating, etc.
- Use chiller waste heat to preheat hot water.
- Use heat pumps.
- Use absorption refrigeration.
- Use thermal wheels, run-around systems, heat pipe systems, and air-to-air exchangers.

Water & sewer (also see "Condensate" and "Pumping")
- Recycle water, particularly for uses with less-critical quality requirements.
- Recycle water, especially if sewer costs are based on water consumption.
- Balance closed systems to minimize flows and reduce pump power requirements.
- Eliminate once-through cooling with water.
- Use the least expensive type of water that will satisfy the requirement.
- Fix water leaks.
- Test for underground water leaks. (It's easy to do over a holiday shutdown.)
- Check water overflow pipes for proper operating level.
- Automate blowdown to minimize it.
- Provide proper tools for wash down -- especially self-closing nozzles.
- Install efficient irrigation.
- Reduce flows at water sampling stations.
- Eliminate continuous overflow at water tanks.
- Promptly repair leaking toilets and faucets.
- Use water restrictors on faucets, showers, etc.
- Use self-closing type faucets in restrooms.
- Use the lowest possible hot water temperature.
- Do not use a heating system hot water boiler to provide service hot water during the cooling season -- install a smaller, more-efficient system for the cooling season service hot water.
- If water must be heated electrically, consider accumulation in a large insulated

storage tank to minimize heating at on-peak electric rates.
• Use multiple, distributed, small water heaters to minimize thermal losses in large piping systems.
• Use freeze protection valves rather than manual bleeding of lines.
• Consider leased and mobile water treatment systems, especially for deionized water.
• Seal sumps to prevent seepage inward from necessitating extra sump pump operation.
• Install pretreatment to reduce TOC and BOD surcharges.
• Verify the water meter readings. (You'd be amazed how long a meter reading can be estimated after the meter breaks or the meter pit fills with water!)
• Verify the sewer flows if the sewer bills are based on them.

"Secondary savings" often provides a bonus

Utility cost reduction projects often have "secondary savings" potentials that are quite significant. Consider the following examples:

A lighting efficiency improvement will often reduce annual air conditioning costs more than it increases annual heating costs – a net savings in addition to the lighting energy savings.

Reduce compressed air leaks and you may improve the efficiency of some of your pneumatic tools and systems as well as reducing the electricity used to provide supply for leaks.

Reduce cooling tower water losses and you will reduce water treatment chemical losses too.

Recycle steam condensate and you will recover some water as well as some heat – and reduce your sewer bill.

Optimize ventilation and you may reduce both heating and air conditioning costs in addition to reducing ventilation blower motor load.

Reduce water consumption and you will often reduce sewer costs.

All of the above are reductions in outside purchases. Projects may also have operation and maintenance benefits in addition to these primary and secondary savings.

1. (Ref. Darrell T. Mears, P.E., 250+ Ways To Reduce Industrial Utility Costs, Optimum Utility Systems, Langhorne, PA, August, 1999.)

VLA Test Memo # 223
Revision 1

VLA Energy Survey 1999

Gaetano A. Stanzione
December 6,1999

Revision 1 Notes:
This revision covers changes on pages 3 and 4.

Section 2.00, Page 3.
1) The table in Section 2.00, Page 3 has been updated for the year 1994.
The data used in this table were incorrectly entered into a spread sheet.
The VLA POWER COST graph (page 4) was also plotted from the same spread sheet.

Section 2.01, Page 4.
1) The VLA POWER COST graph was replotted with the new data.
The dip in VLA power cost during the 1994 year was due
to data that were incorrectly entered into a spread sheet.

2) VLA KWH RATE graph was replaced. A new graph overlays two curves;
the VLA Overall Average KWH Rate and the SEC KWH Rate.
During most years the points overlap except during 1989 through
1993 where the VLA site both generates power and purchases power from SEC.

**Contents** **Page**

**Abstract**
Power consumption at the Very Large Array (VLA) has been monitored for several years. As operating costs continue to rise, energy conservation can play an important role in running the facility more efficiently.

Several events since 1988 have reduced power consumption at the site. The most significant has been the installation of Direct Digital Controllers (DDC) on the antennas. This modification has reduced our annual power consumption by 1,000,000 kilowatt hours. A history of VLA power consumption and major events are plotted in section 2.01.

Monitoring power consumption at all the site transformers helps to identify the major use areas. Surveys were performed in 1986 and 1999. The survey results are tabulated in section 2.02.

Upgrading old equipment offers power savings in many areas. Upgrading the site chillers can reduce power consumption by 157,000 kilowatt hours annually. Changing out old wall air conditioning units will reduce consumption by an additional 40,000 kilowatt hours. Payback periods for both of these items are less then 4 years. Other initial projects are recommended in section 4.00. The total estimated annual savings for the projects listed would be $22,000 and our annual power consumption would be reduced by 363,000 kilowatt hours (3.5% of present consumption).

Budgeting for Energy related projects should be encouraged and reviewed on a regular basis. The cost per kilowatt-hour is on the rise once again.

## 1.00 Discussion And Scope

This energy survey focuses on developing a list of areas and items to address in the coming years and budgets. Projects will be initiated to investigate cost and payback.

There are energy savings available by simply upgrading older and inefficient equipment. Equipment upgrades and replacement should be a part of future budgets. With some equipment it makes sense to wait until the piece fails or the next major overhaul. With others as the analyses might show it makes good sense to replace the equipment immediately.

As an example: The chillers are 25 years old and the cost to rebuild a chiller compressor is greater then 50 percent of the cost of a new chiller. When the next compressor is due to be rebuilt a chiller should be replaced. The newer units will reduce power consumption by 157,000 KWH per year.

Electricity saved now is also saved every year into the future.

**2.00 VLA Energy History**

Even with the efforts to reduce power consumption the overall cost is starting to rise once again. While site consumption has decreased our electric bill has increased.

| Year | Energy KWH Consumption | Electric Bill | Cost/KWH |
|---|---|---|---|
| 1986 | 10821000 | $800,485 | $0.0740 |
| 1994 | 9854400 | $575,946 | $0.0585 |
| 1998 | 9038400 | $569,877 | $0.0632 |
| 1998 Generated | 189000 | $15,000 | $0.0790 |

The VLA has two 1500kw Caterpiller generator sets, left from the Voyager Project. During 1989 to 1993 a decision was made to generate our own site power. The intent was to generate power cheaper than we could buy it for from Socorro Electric Cooperative (SEC). Negotiations with SEC lead us to try a few different operating schedules with different load shedding options. Eventually we started generating full time. Toward the end of 1993 a rate was negotiated with SEC and we started purchasing power once again. These rate negotiations with Socorro Electric Cooperative contributed to reducing the VLA electric bill substantially.

During 1993-1997 the VLA antennas were retrofitted with DDC controls on the Vertex Room air conditioning. This upgrade has reduced site kilowatt hour consumption by 8-10% or one million kilowatt hours per year. At today's cost this KWH reduction translates into an estimated $70,000 saved annually. An additional $7200 in demand charges are also saved.

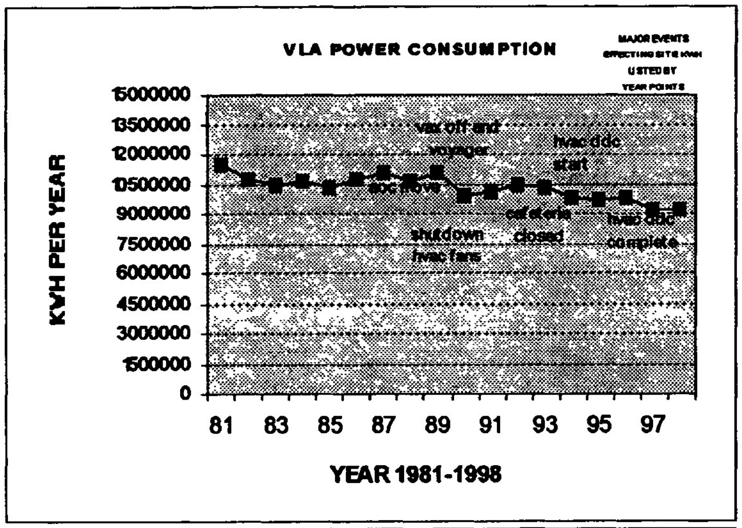
**2.01 Major Events**

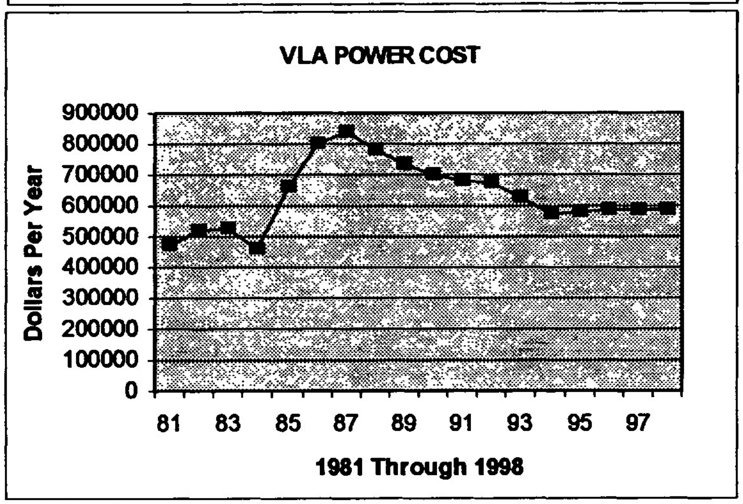
From 1988 to 1997 there were several events that reduced KWH consumption at the site. Site power consumption is plotted from 1981 through 1998 with the events noted on the graph during the year they took place. A plot of yearly power cost is also given.

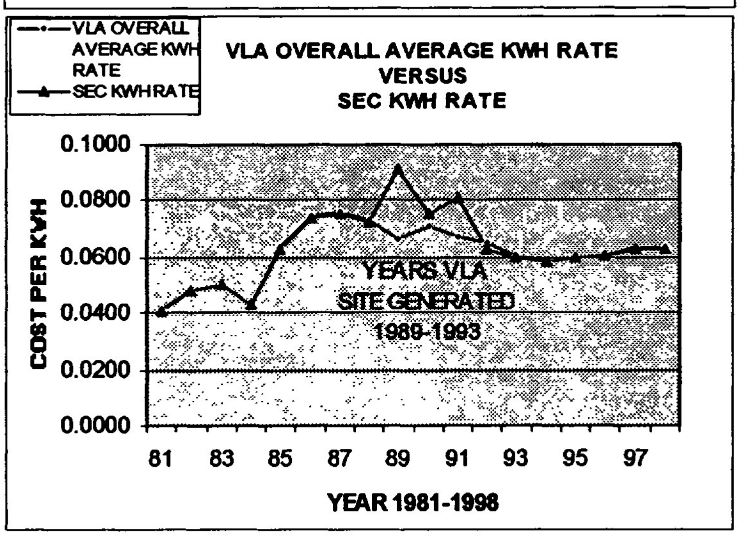
Events:

a. Move to Array Operations Center (AOC) - November of 1988
b. Relocate Vax to AOC - November of 1988
c. Voyager- August of 1989
d. The installation of DDC Controls on the VLA antenna vertex room heating and air conditioning system – November 1993 to October 1997
e. Control Building HVAC system building and computer fans were turned off about1990/1991.
f. Cafeteria was shutdown – February of 1993.

## VLA Power Consumption And Power Cost From 1981 Through 1998



**2.02 Monitoring Power Consumption 1986 and 1999**
In August of 1986 a partial power consumption breakdown were gathered. A power monitor was placed at different transformers to collect usage data. Collections points included the main transformers at the Control Building, Cafeteria, Antenna Building, Vax/Slob (Control Building Annex), Technical Services Area (MD Panel) and one Antenna.

In September of 1999 we also collected usage data to compare the different areas. We will monitor the same transformers in January 2000 to check the winter loading. The table below compares the surveys in the summers of 1986 and 1999.

**Power Monitoring 1986 and 1999**

| | Ranges | Ranges |
|---|---|---|
| Site Area | August, 1986 | September, 1999 |
| | Kilowatts | Kilowatts |
| Antenna | 18.3 | 19.25 |
| (19kw/antenna * 27) | 494 | 519.75 |
| Control Building | 385 | 295 |
| MD Panel | 68.8 | 89.05 |
| Cafeteria Building | 22.09 | 10.72 |
| Antenna Building | 16.24 | 37.27 |
| Vax/Slob | 45.26 | 2.2 |

The comparison shows that our two main consumers of energy are the Antennas and the Control Building. It also shows that in some areas consumption has increased.

**3.00 Listing of Energy Items To Review**
The listing will be maintained and updated yearly. Projects will be discussed with management and assigned as the budget allows.

**3.01 Upgrade Equipment**
A) Possible alternates for Heating, Ventilating and Air Conditioning (HVAC) equipment.
1. Technical Services HVAC wall units: Install heat pump wall unit.
2. Cryogenics at Tech Services: Install split system heat pump unit.
3. Antenna Barn: Replace furnace in the VLBA Shop Area.
4. Antenna Barn: Install heat pump wall unit.
5. Warehouse offices HVAC: Install heat pump wall unit.
6. Servo HVAC: Install heat pump wall unit.
7. Cafeteria Heat Pumps: Install newer heat pumps.
8. Visitor Sleeping Quarters: Install heat pump wall units.
9. Control Building: Install new Chillers.

B) Energy efficient motors where justified.
C) Cafeteria: Install a second smaller hot water heater. In progress.
D) Variable Frequency Drives (where applicable).

E) Soft Starts (where applicable).
F) Capacitors to improve power factor (if we pay for low power factor).

**3.02 Lighting**
A) Review all lighting and replace with energy efficient lights and ballasts.
Use lower wattage light bulbs where possible.
B) Low pressure sodium or LED instead of incandescent.
C) Turn off light stickers.
D) Motion sensors- Identify locations inside and outside of buildings.
E) Skylights.

**3.03 Operation (buildings/antennas)**
A) Antennas
1. Can some of the equipment be turned off? Pedestal Room air conditioning?
2. Azimuth and Elevation Gearbox Fans. Investigate the need for fans. The cost to operate drive fans is $40,000 a year.
3. Reduce or widen set point temperature range in Pedestal room.
4. Stagger antennas during slew can reduce demand?
5. Feed heaters: Presently all the heaters come on at one time. Redesign for individual switching or automate using weather data.
6. Insulate upper pedestal. Cover openings to yoke.
7. Insulate vertex room.
8. Brushless DC drives for the antennas (manhour maintenance savings).

B) Use swamp coolers for cooling in place of wall units (in progress).
C) Investigate chilled water requirements.
D) Do we need the computer air system any longer?
E) Install enthalpy controller on building system. Controller is already in hand.
F) Reduce seal water usage at Cooling Tower Sump Pump.

**3.04 Buildings**
A) Insulated windows.
B) Control building boiler for humidity control. Is humidity control required any longer?
C) Waste oil heater mechanics area.
D) Warehouse add ceiling fans min (4)- personnel comfort and mixing.

**3.05 Other**
A) Solar Panels (are still too expensive)

## 4.00 Payback Analyses Table

Payback Analyses use the simple payback method. Projects taken from sections 3.01A (1-6), 3.01B, 3.02A, and 3.04C.

| | Payback Table | Kilowatt-Hours | LPG Saved | Equipment | **Energy Savings | Payback |
|---|---|---|---|---|---|---|
| | Payback Analyses | Saved Annually | Annually | Cost | Annually | Years |
| 1 | Control Building Chillers | | | | | |
| | Replace one Chiller | 157000 | | $38,000 | $10,000 | 3.8 |
| | *Replace two Chillers | 157000 | | $76,000 | $10,000 | 7.6 |
| 2 | Wall Air Conditioning Units | | | | | |
| | For ten units | 42000 | | $8,000 | $2,600 | 3.1 |
| 3 | Lighting Ballasts Replacement | | | | | |
| | Four bulb ballast (200) | 32000 | | $6,000 | $2,000 | 3 |
| | Two bulb ballast (390) | 17846 | | $7,800 | $1,124 | 6.94 |
| 4 | Energy Efficient Motors (HVAC System) mfg claims 3%-5% savings/yr | | | | | |
| | 6-15hp motors @4%/yr | 29500 | | $3,000 | $1,854 | 1.7 |
| 5 | Antenna Barn Furnace | | | | | |
| | Est. 10% savings new unit | | 276Gal. LPG | $800 | $276 | ~3 |
| 6 | Waste Oil Heater | | | | | |
| | If only 500 gallons of waste available. Supplement with #2 diesel | 50000 | | $6,000 | $2,000 | 3 |
| 7 | Cryogenics Area Air Conditioning | | | | | |
| | New Split System Heat Pump | 34900 | | $5,000 | $2,200 | 2.2 |
| | | | | | | |
| | Overall (with one chiller) | 363246 | | $74,600 | $22,054 | 3.38 |
| | Overall (with two chiller) | 363246 | | $112,600 | $22,054 | 5.11 |
| | | | | | | |
| | * Presently we only operate one chiller. | | | | | |
| | Cost to rebuild a compressor is >50% of the cost of a new chiller. | | | | | |
| | **Energy savings based on a 90 day heating season and a 120 day cooling season. | | | | | |

## 5.00 Recommendations

This survey is a only a guide. Each of the areas listed should be reviewed closely and where there is a potential for reducing consumption a payback analysis should be completed. The method of analysis can be reviewed by the Business Division.

More important is that NRAO develop an energy budget. Whenever an energy project passes the payback criteria it should be implemented in some reasonable time frame.

The seven projects listed in section 4.00 should be completed. Other projects in section 3.00 such as Brushless DC Motors, Antenna Drive Motor Fan circuitry (which will reduce fan usage), Feed Heaters, Enthalpy Controllers should be reviewed. If the payback criteria is met they should be submitted for approval.

For general information a list of ways to reduce utility costs are included in Appendix A.

# Appendix A

250+ Ways To Reduce Industrial Utility Costs (Mears, 1999)

Blowers (also see "Motors")

- Locate air intakes to obtain appropriate air quality and best efficiency.
- Use smooth, well-rounded air inlet ducts or cones for air intakes.
- Minimize blower inlet and outlet obstructions.
- Clean screens and filters regularly.
- Use backward-inclined blower wheel designs.
- Minimize blower speed.
- Consider using a two-speed motor and running at the low speed whenever possible.
- Use low-slip or no-slip belts.
- Check belt tension regularly.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable blower loads.
- Use energy-efficient motors for continuous or near-continuous operation. Related article.
- Use properly-sized ductwork with appropriate bends and transitions.
- Eliminate ductwork leaks.
- Turn blowers off when they are not needed.

Buildings (also see "HVAC")

- Seal exterior cracks/openings/gaps with caulk, gasketing, weatherstripping, etc.
- Consider new thermal doors, thermal windows, roofing insulation, etc.
- Install windbreaks near exterior doors.
- Replace single-pane glass with insulating glass.
- Consider covering some window and skylight areas with insulated wall panels inside the building.
- If visibility is not required but light is required, consider replacing exterior windows with insulated glass block.
- Consider tinted glass, reflective glass, coatings, awnings, overhangs, draperies, blinds, and shades for sunlit exterior windows.
- Use landscaping to advantage.
- Add vestibules or revolving doors to primary exterior personnel doors.
- Consider automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
- Use intermediate doors in stairways and vertical passages to minimize building stack effect.
- Use dock seals at shipping and receiving doors.
- Bring cleaning personnel in during the working day or as soon after as possible to minimize lighting and HVAC costs.

Chillers (also see "Refrigeration" and "Cooling Towers")

- Increase the chilled water temperature set point if possible.

• Use the lowest temperature condenser water available that the chiller can handle.
• Clean heat exchangers when fouled.
• Optimize condenser water flow rate and refrigerated water flow rate.
• Replace old chillers or compressors with new higher-efficiency models. Related article.
• Use water-cooled rather than air-cooled chiller condensers.
• Use energy-efficient motors for continuous or near-continuous operation. Related article.
• Specify appropriate fouling factors for condensers.
• Use the most efficient refrigerant.
• Do not overcharge refrigerant.
• Do not overcharge oil.
• Install a control system to coordinate multiple chillers.
• Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple chillers.
• Run the chillers with the lowest operating costs to serve base load.
• Avoid oversizing -- match the connected load.
• Isolate off-line chillers and cooling towers.
• Establish a chiller efficiency-maintenance program.

Compressed air (also see "Compressors" and related article)
• Install a control system to coordinate multiple air compressors.
• Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple air compressors.
• Avoid oversizing -- match the connected load.
• Load up modulation-controlled air compressors. (They use almost as much power at partial load as at full load.)
• Turn off the back-up air compressor until it is needed.
• Reduce air compressor discharge pressure to the lowest acceptable setting. (This will reduce compression energy requirements and compressed air leakage rates.)
• Use the highest reasonable dryer dew point settings.
• Turn off refrigerated and heated air dryers when the air compressors are off.
• Use a control system to minimize heatless desiccant dryer purging.
• Minimize purges, leaks, excessive pressure drops, and condensation accumulation.
• Use drain controls instead of continuous air bleeds through the drains.
• Consider engine-driven or steam-driven air compression to reduce electrical demand charges.
• Change the electric motors to an energy-efficient designs. Related article.
• Replace standard v-belts with high-efficiency cogged v-belts as the old v-belts wear out.
• Use a small air compressor for HVAC load when production load is off.
• Take air compressor intake air from the coolest (but not air conditioned) location.
• Use an air-cooled aftercooler to heat building makeup air in winter.

- Be sure that heat exchangers are not fouled (e.g. -- with oil).
- Be sure that air/oil separators are not fouled.
- Monitor pressure drops across suction and discharge filters and clean or replace filters promptly upon alarm.
- Use a properly sized compressed air storage receiver.
- Minimize disposal costs by using lubricant that is fully demulsible and an effective oil-water separator.
- Consider alternatives to compressed air such as blowers for cooling, hydraulic rather than air cylinders, electric rather than air actuators, and electronic rather than pneumatic controls.
- Use nozzles or venturi-type devices rather than blowing with open compressed air lines.
- Check for leaking drain valves on compressed air filter/regulator sets. Certain rubber-type valves may leak continuously after they age and crack.
- In dusty environments, control packaging lines with high-intensity photocell units instead of standard units with continuous air purging of lenses and reflectors.
- Establish a compressed air efficiency-maintenance program.

Compressors

- Consider variable speed drive for variable load on positive displacement compressors.
- Use a synthetic lubricant if the compressor manufacturer permits it.
- Be sure lubricating oil temperature is not too high (oil degradation and lowered viscosity) and not too low (condensation contamination).
- Change the oil filter regularly.
- Periodically inspect compressor intercoolers for proper functioning.
- Use waste heat from a very large compressor to power an absorption chiller or preheat process or utility feeds.
- Establish a compressor efficiency-maintenance program.

Condensate

- Return steam condensate to boiler feedwater where the return system cost is justified.
- Inspect steam traps regularly.
- Use HVAC condensate to avoid make-up water and sewer costs (e.g. -- use HVAC condensate for cooling tower make-up water).

Cooling towers

- Control cooling tower fans based on leaving water temperatures.
- Control to the optimum water temperature as determined from cooling tower and chiller performance data.
- Use two-speed or variable-speed drives for cooling tower fan control if the fans are few. Stage the cooling tower fans with on-off control if there are many.
- Turn off unnecessary cooling tower fans when loads are reduced.
- Cover hot water basins (to minimize algae growth that contributes to fouling).

• Balance flow to cooling tower hot water basins.
• Periodically clean plugged cooling tower water distribution nozzles.
• Install new nozzles to obtain a more-uniform water pattern.
• Replace splash bars with self-extinguishing PVC cellular-film fill.
• On old counterflow cooling towers, replace old spray-type nozzles with new square-spray ABS practically-non-clogging nozzles.
• Replace slat-type drift eliminators with high-efficiency, low-pressure-drop, self-extinguishing, PVC cellular units.
• If possible, follow manufacturer's recommended clearances around cooling towers and relocate or modify structures, signs, fences, dumpsters, etc. that interfere with air intake or exhaust.
• Optimize cooling tower fan blade angle on a seasonal and/or load basis.
• Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
• Use a velocity pressure recovery fan ring.
• Divert clean air-conditioned building exhaust to the cooling tower during hot weather.
• Re-line leaking cooling tower cold water basins.
• Check water overflow pipes for proper operating level.
• Optimize chemical use.
• Consider side stream water treatment.
• Restrict flows through large loads to design values.
• Shut off loads that are not in service.
• Locate make-up and blowdown tie-ins to minimize heat tracing cost in winter.
• Take blowdown water from the return water header.
• Optimize blowdown flow rate.
• Automate blowdown to minimize it.
• Send blowdown to other uses or to the cheapest available sewer allowed. (Remember, the blowdown does not have to be removed at the cooling tower. It can be removed anywhere in the piping system.)
• Implement a cooling tower winterization plan to minimize ice build-up.
• Avoid simultaneous water heating and cooling in cold weather.
• Install interlocks to prevent fan operation when there is no water flow.
• Establish a cooling tower efficiency-maintenance program.

Drives (also see "Motors")

• Use variable-speed drives for large variable loads. (Remember that engines can be variable-speed too.)
• Use high-efficiency gear sets.
• Use precision alignment.
• Check belt tension regularly.
• Eliminate variable-pitch pulleys.
• Use synchronous belts as no-slip alternatives to v-belts.
• Use synthetic lubricants for large gearboxes.
• Eliminate eddy current couplings.

• When they're not needed, shut them off.

Electricity (also see "Lighting" and "Motors")

• Shop for best price in the deregulated electricity market. Related article.
• Know your historical demand profile so you can make the best deal in the deregulated electricity market.
• If your load factor is poor, aggregate with other sites that have higher load factors so you can make the best deal in the deregulated electricity market.
• Shift loads to off-peak times if possible.
• Know the cost of setting a new electric peak demand and set alarms and shut down equipment accordingly.
• Stagger start-up times for equipment with large starting currents to minimize load peaking.
• Use standby electric generation equipment for on-peak high load periods.
• Test emergency generators during on-peak high load periods.
• Delay start-up of new equipment to prevent a new summer peak.
• If possible, shut off a piece of equipment before starting the alternate piece.
• Consider alternative electric rate schedules (e.g. -- interruptible rate).
• Take advantage of utility rebate programs (e.g. -- lighting upgrade, thermal storage, energy efficient motors).
• Correct power factor to at least 90% under rated load conditions.
• Buy the substation, transformer, etc. from the utility.
• Relocate transformers close to main loads.
• Set transformer taps to optimum settings.
• Disconnect primary power to transformers that do not serve any active loads (e.g. -- seasonal loads or surplused transformers).
• Consider on-site electric generation or cogeneration.
• Have the utility "buy out" your cogeneration plan (i.e. -- reduce your rate if you will terminate the project).
• Check electric meter printouts and electric bills for use during outages and holiday shut-down periods. (You'd be amazed at the true stories that can be told. Clerks sometimes fill in gaps!)
• Shut off unnecessary computers, printers, and copiers at night.
• Buy Energy Star compliant products.

Fans (also see "Motors")

• Use smooth, well-rounded air inlet cones for fan air intakes.
• Avoid poor flow distribution at the fan inlet.
• Minimize fan inlet and outlet obstructions.
• Clean screens, filters, and fan blades regularly.
• Use airfoil-shaped fan blades.
• Minimize fan speed.
• Consider using a two-speed motor and running at the low speed whenever possible.
• Use low-slip or no-slip belts.

• Check belt tension regularly.

• Eliminate variable pitch pulleys.
• Use variable speed drives for large variable fan loads.
• Use energy-efficient motors for continuous or near-continuous operation. Related article.
• Use properly-sized ductwork with appropriate bends and transitions.
• Eliminate ductwork leaks.
• Turn fans off when they are not needed.

Fire protection systems
• Test electric fire pumps during electrical off-peak periods.
• Automate pressure maintenance pumps to only run when water pressure is low.
• Check for continuous overflow at storage tank due to an open feed.
• Check water overflow pipes for proper operating level.
• Consider using the storage tank for refrigerated water thermal storage.

Heat exchangers
• Specify appropriate heat exchanger fouling factors.
• Maintain "self-cleaning" fluid velocities.
• Clean heat exchangers when excessively fouled.
• Turn off the flow when the heat exchanger is out of service.
• Routinely log process data for assessment of fouling and establish a heat exchanger efficiency-maintenance program.

HVAC (Heating / Ventilation / Air Conditioning) (also see "Blowers" and "Buildings" and "Chillers" and "Cooling towers" and "Fans")
• Tune up the HVAC control system.
• Consider installing a building automation system (BAS) or energy management system (EMS) or restoring an out-of-service one.
• Balance the system to minimize flows and reduce blower/fan/pump power requirements.
• Eliminate or reduce reheat whenever possible.
• Prevent unauthorized thermostat adjustments.
• Use appropriate HVAC thermostat setback.
• Raise "cool" settings and lower "heat" settings to appropriate levels.
• Use morning pre-cooling in summer and pre-heating in winter (i.e. -- before electrical peak hours).
• Use building thermal lag to minimize HVAC equipment operating time.
• In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials.
• In summer during unoccupied periods, allow temperatures to rise as high as possible without damaging stored materials.
• Improve control and utilization of outside air.

• Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.
• Reduce HVAC system operating hours (e.g. -- night, weekend).
• Optimize ventilation.
• Ventilate only when necessary. To allow some areas to be shut down when unoccupied, install dedicated HVAC systems on continuous loads (e.g. -- computer rooms).
• Provide dedicated outside air supply to kitchens, cleaning rooms, combustion equipment, etc. to avoid excessive exhausting of conditioned air.
• Use evaporative cooling in dry climates.
• Reduce humidification or dehumidification during unoccupied periods.
• Use atomization rather than steam for humidification where possible.
• Clean HVAC unit coils periodically and comb mashed fins.
• Upgrade filter banks to reduce pressure drop and thus lower fan power requirements.
• Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate.
• Check pneumatic controls air compressors for proper operation, cycling, and maintenance.
• Isolate air conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains.
• Install ceiling fans to minimize thermal stratification in high-bay areas.
• Relocate air diffusers to optimum heights in areas with high ceilings.
• Consider reducing ceiling heights.
• Eliminate obstructions in front of radiators, baseboard heaters, etc.
• Check reflectors on infrared heaters for cleanliness and proper beam direction.
• Use professionally-designed industrial ventilation hoods for dust and vapor control.
• Use local infrared heat for personnel rather than heating the entire area.
• Use spot cooling and heating (e.g. -- use ceiling fans for personnel rather than cooling the entire area).
• Purchase only high-efficiency models for HVAC window units.
• Put HVAC window units on timer control.
• Improve crude temperature control of multiple HVAC window units.
• Control infrared heaters based on ambient temperature.
• Don't oversize cooling units. (Oversized units will "short cycle" which results in poor humidity control.)
• Use a system of multiple modular boilers instead of one large boiler.
• Install multi-fueling capability and run with the cheapest fuel available at the time.
• Consider dedicated make-up air for exhaust hoods. (Why exhaust the air conditioning or heat if you don't need to?)
• Minimize HVAC fan speeds.
• Consider desiccant drying of outside air to reduce cooling requirements in humid climates.
• Consider ground source heat pumps.
• Seal leaky HVAC ductwork.
• Seal all leaks around coils.
• Repair loose or damaged flexible connections.

• Eliminate simultaneous heating and cooling during seasonal transition periods.
• Consider directing clean conditioned exhaust air to the inlet of a cooling tower, air-cooled condenser, or evaporative cooler when doing so will reduce energy requirements.
• Zone HVAC air and water systems to minimize energy use.
• Inspect, clean, lubricate, and adjust damper blades and linkages.
• Establish an HVAC efficiency-maintenance program.

Insulation

• Repair damaged insulation.
• Insulate any hot or cold metal or insulation.
• Replace wet insulation.
• Use an infrared gun to check for cold wall areas during cold weather or hot wall areas during hot weather.
• Consider adding insulation to water heaters, etc. located in unheated/uncooled spaces.
• Insulate HVAC ducts running outside and through unoccupied spaces.
• Take vapor barriers and insulation coverings very seriously.

Lighting (also see "Electricity")

• Reduce excessive illumination levels to standard levels using switching, delamping, etc. (Know the electrical effects before doing delamping.)
• Aggressively control lighting with clock timers, delay timers, photocells, and/or occupancy sensors.
• Install efficient alternatives to incandescent lighting, mercury vapor lighting, etc. Efficiency (lumens/watt) of various technologies range from best to worst approximately as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, mercury vapor, incandescent.
• Select ballasts and lamps carefully with high power factor and long-term efficiency in mind.
• Upgrade obsolete fluorescent systems to T-8 lamps and electronic ballasts. Related article.
• Consider T-5 fluorescent lighting systems for new construction.
• Consider lowering the fixtures to enable using less of them.
• Consider painting the walls a lighter color and using less lighting fixtures or lower wattages.
• Use task lighting and reduce background illumination.
• Re-evaluate exterior lighting strategy, type, and control. Control it aggressively.
• Change exit signs from incandescent to LED.

Miscellaneous

• Meter any unmetered utilities. Know what is normal efficient use. Track down causes of deviations.
• Shut down spare, idling, or unneeded equipment.
• Make sure that all of the utilities to "mothballed" areas are turned off -- including utilities like compressed air and cooling water.
• Install automatic control to efficiently coordinate multiple air compressors, chillers, cooling tower cells, boilers, etc.

• Renegotiate utilities contracts to reflect current loads and variations.
• Consider buying utilities from neighbors, particularly to handle peaks.
• Leased space often has low-bid inefficient equipment. Consider upgrades if your lease will continue for five or more years.
• Take as much of the sales tax exclusion on manufacturing utilities as you can take.
• Avoid late payment charges.
• Use alternative sampling systems to eliminate sample hoods, thus reducing water, sewer, and ventilation requirements.
• Stop using rental equipment for long-term requirements. Install permanent high-efficiency equipment where appropriate.
• Adjust fluid temperatures within acceptable limits to minimize undesirable heat transfer in long pipelines.
• Minimize use of flow bypasses and minimize bypass flow rates.
• Provide restriction orifices in purges (nitrogen, steam, etc.).
• Eliminate unnecessary flow measurement orifices.
• Consider alternatives to high pressure drops across valves.
• Turn off winter heat tracing that is on in summer.

Motors (also see "Drives" and "Electricity")
• Properly size to the load for optimum efficiency.
• Use energy-efficient motors where economical. Related article.
• Use synchronous motors to improve power factor.
• Check alignment.
• Check for under-voltage and over-voltage conditions.
• Balance the three-phase power supply.
• Require efficiency restoration from motor rewinding.

Nitrogen & other specialty gases
• Shop for best specialty gas prices.
• Generate nitrogen or oxygen with a membrane system where lower quality than cryogenic will suffice.
• Use liquid nitrogen vaporization for cooling.
• Use liquid nitrogen vaporization for vent stream VOC condensation.
• Periodically survey gas systems (especially oxygen, nitrogen, and other high cost gases) using ultrasonic and other leak detection methods and fix leaks.

Pumping (also see "Motors" and "Water & sewer")
• Operate pumping near best efficiency point.
• Modify pumping to minimize throttling.
• Adapt to wide load variation with variable speed drives or sequenced control of smaller units.
• Stop running both pumps -- add an auto-start for an on-line spare or add a booster pump in a problem area.
• Use booster pumps for small loads requiring higher pressures.

• Increase fluid temperature differentials to reduce pumping rates.
• Repair seals and packing to minimize water waste.
• Balance the system to minimize flows and reduce pump power requirements.
• Use siphon effect to advantage: don't waste pumping head with a free-fall return.

Refrigeration (also see "Chillers" and "Cooling towers" and "HVAC")
• Use water-cooled condensers rather than air-cooled condensers.
• Challenge the need for refrigeration, particularly for old batch processes.
• Avoid over sizing -- match the connected load.
• Consider gas-powered refrigeration equipment to minimize electrical demand charges.
• Use "free cooling" to allow chiller shutdown in cold weather.
• Use refrigerated water loads in series if possible.
• Convert firewater or other tanks to thermal storage.
• Don't assume that the old way is still the best -- particularly for energy-intensive low temperature systems.
• Correct inappropriate brine or glycol concentration that adversely affects heat transfer and/or pumping energy.
• If it sweats, insulate it. If it is corroding, replace it first. (Want to hear a sad story about how a large amount of refrigerant was lost for ignoring this one?)
• Consider adding hot gas bypass if it will reduce power consumption.
• Make adjustments to minimize hot gas bypass operation.
• Insulate hot gas lines that are inside buildings.
• Inspect moisture/liquid indicators.
• Consider change of refrigerant type if it will improve efficiency.
• Check for correct refrigerant charge level.
• Inspect the purge for air and water leaks.
• Establish a refrigeration efficiency-maintenance program.

Steam (also see "Boilers")
• Fix steam leaks and condensate leaks.
• Accumulate work orders for repair of steam leaks that can't be fixed during the heating season due to system shutdown requirements. Tag each such leak with a durable tag with a good description.
• Use let-down steam turbines to produce lower steam pressures.
• Use more-efficient steam desuperheating methods.
• Inspect steam traps regularly and repair malfunctioning traps promptly.
• Challenge orifice traps.
• Consider recovery of vent steam (e.g. -- on large flash tanks).
• Use waste steam for water heating.
• Use an absorption chiller to condense exhaust steam before returning the condensate to the boiler.
• Use electric pumps instead of steam eductors for sump clean-out, or at least provide reliable automatic shut-off.

• Establish a steam efficiency-maintenance program.

Steam turbines (also see "Boilers" and "Steam")

• Re-evaluate options if efficiency is less than 65% (e.g. -- avoid small crude steam turbines).
• Use steam turbines for large volume pressure letdown.
• Use a piggy-back absorption system where existing chillers are driven by steam turbines.
• Establish a steam turbine efficiency-maintenance program.

Waste recovery

• Recover heat from flue gas, engine cooling water, engine exhaust, low pressure waste steam, drying oven exhaust, boiler blowdown, etc.
• Recover fuel from vent streams.
• Recover heat from thermal oxidizer or incinerator off-gas.
• Use waste heat for fuel oil heating, boiler feedwater heating, outside air heating, etc.
• Use chiller waste heat to preheat hot water.
• Use heat pumps.
• Use absorption refrigeration.
• Use thermal wheels, run-around systems, heat pipe systems, and air-to-air exchangers.

Water & sewer (also see "Condensate" and "Pumping")

• Recycle water, particularly for uses with less-critical quality requirements.
• Recycle water, especially if sewer costs are based on water consumption.
• Balance closed systems to minimize flows and reduce pump power requirements.
• Eliminate once-through cooling with water.
• Use the least expensive type of water that will satisfy the requirement.
• Fix water leaks.
• Test for underground water leaks. (It's easy to do over a holiday shutdown.)
• Check water overflow pipes for proper operating level.
• Automate blowdown to minimize it.
• Provide proper tools for wash down -- especially self-closing nozzles.
• Install efficient irrigation.
• Reduce flows at water sampling stations.
• Eliminate continuous overflow at water tanks.
• Promptly repair leaking toilets and faucets.
• Use water restrictors on faucets, showers, etc.
• Use self-closing type faucets in restrooms.
• Use the lowest possible hot water temperature.
• Do not use a heating system hot water boiler to provide service hot water during the cooling season -- install a smaller, more-efficient system for the cooling season service hot water.
• If water must be heated electrically, consider accumulation in a large insulated

storage tank to minimize heating at on-peak electric rates.
• Use multiple, distributed, small water heaters to minimize thermal losses in large piping systems.
• Use freeze protection valves rather than manual bleeding of lines.
• Consider leased and mobile water treatment systems, especially for deionized water.
• Seal sumps to prevent seepage inward from necessitating extra sump pump operation.
• Install pretreatment to reduce TOC and BOD surcharges.
• Verify the water meter readings. (You'd be amazed how long a meter reading can be estimated after the meter breaks or the meter pit fills with water!)
• Verify the sewer flows if the sewer bills are based on them.

"Secondary savings" often provides a bonus

Utility cost reduction projects often have "secondary savings" potentials that are quite significant. Consider the following examples:

A lighting efficiency improvement will often reduce annual air conditioning costs more than it increases annual heating costs – a net savings in addition to the lighting energy savings.

Reduce compressed air leaks and you may improve the efficiency of some of your pneumatic tools and systems as well as reducing the electricity used to provide supply for leaks.

Reduce cooling tower water losses and you will reduce water treatment chemical losses too.

Recycle steam condensate and you will recover some water as well as some heat – and reduce your sewer bill.

Optimize ventilation and you may reduce both heating and air conditioning costs in addition to reducing ventilation blower motor load.

Reduce water consumption and you will often reduce sewer costs.

All of the above are reductions in outside purchases. Projects may also have operation and maintenance benefits in addition to these primary and secondary savings.

1. (Ref. Darrell T. Mears, P.E., 250+ Ways To Reduce Industrial Utility Costs, Optimum Utility Systems, Langhorne, PA, August, 1999.)