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Energy Management Diagnostics

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ENERGY MANAGEMENT DIAGNOSTIC

U.S. Environmental Protection Agency

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ENERGY MANAGEMENT DIAGNOSTIC

INTRODUCTION

Most of the wastewater treatment facilities constructed in the United States were either designed or under construction by the early 1970's, at a time when energy was considered to be relatively inexhaustible, dependable and inexpensive. Because of this, these facilities were designed with an emphasis on performance, not energy efficency. Since the 1973-1976 OPEC oil embargo, energy availability and costs have become major concerns to wastewater treatment managers. Energy costs (both fuel and electricity) represent a significant portion of the total costs of operating today's wastewater utilities, in many instances accounting for 20-25% of the total operating cost. It is critical for utility managers to identify energy management techniques to control energy usage and costs without sacrificing utility operations.

This manual will familiarize local officials and utility managers with the principles and practices of sound energy management, specifically applied to wastewater utility operations. To accomplish this, the manual presents the following:

- a review of energy usage in wastewater treatment;
- a method for performing an energy management audit; and
- a series of checklists for energy management in a wastewater facility.

From this, managers will become familiar with: the types of energy usage in their facility, the energy conservation and management techniques available to control energy consumption and costs, and the approach to evaluate and implement energy management practices within their facilities.

ENERGY USAGE IN WASTEWATER TREATMENT

An understanding of energy usage and its cost implications is important to an understanding of energy management alternatives. A review of energy usage in wastewater treatment must consider:

- what sources of energy are used;
- where energy is used in the facility; and
- how energy is used.

What Sources of Energy Are Used

Several sources of energy are used in wastewater treatment including electricity, fuel oil, natural gas, methane and gasoline. In addition both wood and solar energy are beginning to be used in certain instances for heating. Of the types of energy used, electricity accounts for about 75% of the consumption, primarily to operate electric motors throughout the facility. Fuel oil, natural gas and methane gas are used for building heating, sludge treatment and sludge disposal. Gasoline is used for vehicles involved in operations, maintenance and sludge disposal. The selection of a particular fuel depends on its availability and costs and the type of treatment process being used.

In addition to energy used directly at the treatment facility, secondary energy is required to manufacture materials used in the treatment process. This includes both the materials used in constructing the facility, such as cement and steel, and the materials consumed in the treatment process, such as chemicals. Secondary energy requirements for construction materials is generally not a concern of utility managers, however, the secondary energy requirements for consumables should be considered. As energy costs increase, those chemicals that have large energy requirements to manufacture are likely to increase in cost faster than other chemicals. This may affect the selection of energy conservation options. Exhibit 1 lists the chemicals commonly used in wastewater treatment and the estimated energy requirements for production. Additional information can be found in EPA publication MCD-32, "Energy Conservation in Municipal Wastewater Treatment."

Where Energy Is Used

The major areas of energy consumption within wastewater facilities are in the treatment processes themselves. For a typical wastewater facility, major energy consumption is required for pumping, secondary treatment, sludge dewatering and sludge disposal. Less significant amounts of energy are required for buildings and structures which require energy for heating, ventilating, air conditioning and electrical lighting. Exhibit III-2 illustrates the relative energy usage for various treatment processes for a wastewater facility.

EXHIBIT 1

ESTIMATED ENERGY REQUIREMENTS FOR THE PRODUCTION OF CONSUMABLE MATERIALS

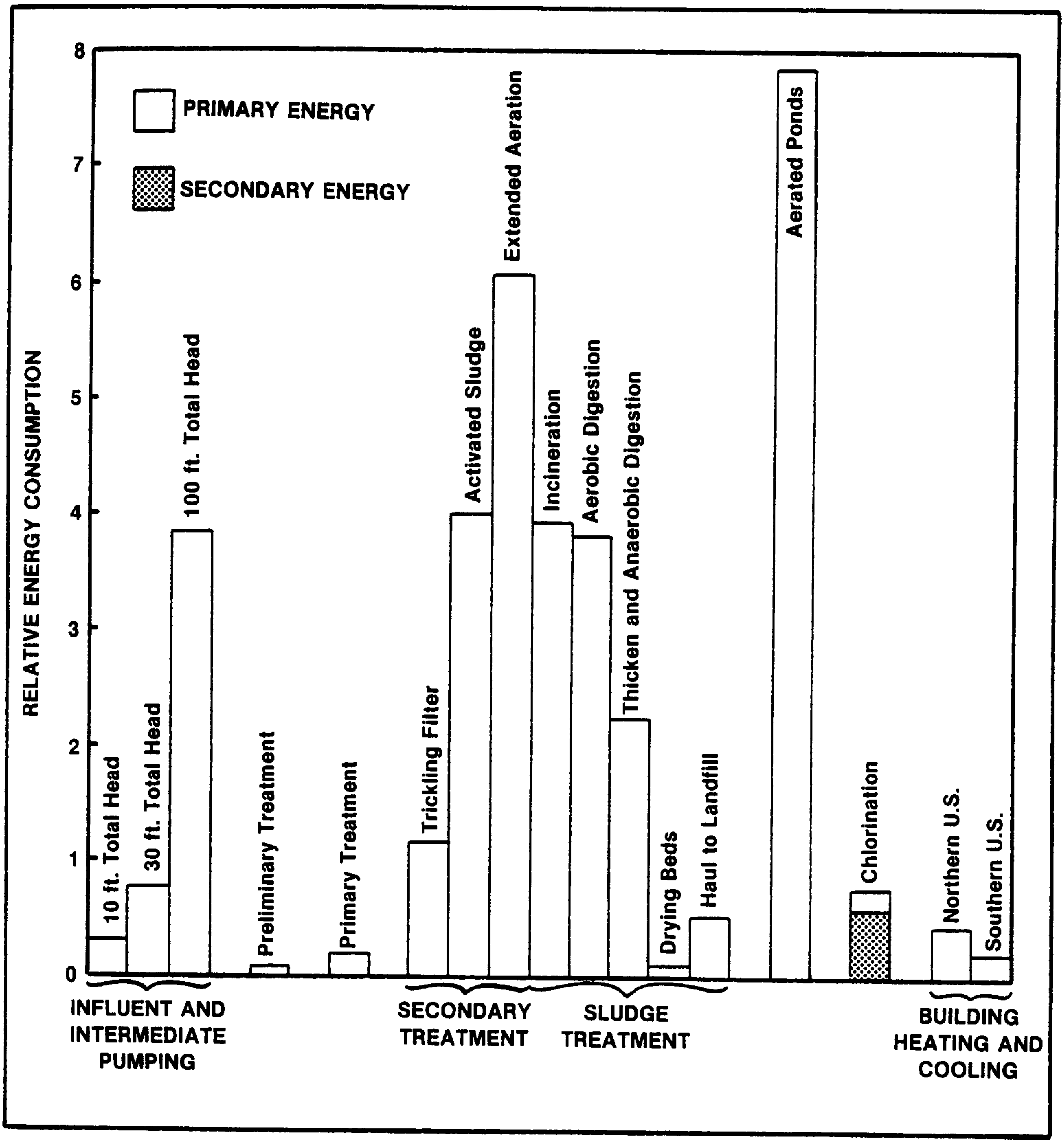
Material	Fuel Million Btu/ton	Electricity kwh/lb
Activated Carbon	102*	4.9
Alum	2*	0.1
Ammonium Hydroxide	41*	2.0
Carbon Dioxide	2	0.1*
Chlorine	42	2.0*
Ferric Chloride	10	0.5*
Lime (Calcium Oxide)	5.5*	0.3
Methanol	36*	1.7
Oxygen	5.3	0.25*
Polymer	3*	0.1
Salt (Sodium Chloride)		
Evaporated	4*	0.2
Rock & Solar	0.5	0.024*
Sodium Hydroxide	37	1.8*
Sulfur Dioxide	0.5	0.024*
Sulfuric Acid	1.5*	0.1

*Indicates principal type of energy used in production.

Energy Conservation in Municipal Wastewater Treatment, MCD-32.

EXHIBIT 2

TYPICAL ENERGY USE PROFILE
FOR
WASTEWATER TREATMENT PROCESSES



Source: Processes-Not Products-Biggest Energy-Saving Factors Water & Sewage Works, November 1980

It is important to understand where energy is consumed in the utility so that the analysis of alternatives is properly directed. For example, as indicated in Exhibit 2, "building energy," for lighting, heating and cooling, represents only 10% of the total energy requirements of the facility. If this energy consumption can be reduced, say 20%, through alternative energy conservation options, it only reduces total energy usage by 2%. However, even a modest reduction in the percentage of energy consumption in secondary treatment or sludge treatment can have a significant impact.

Energy usage, by wastewater treatment process, is identified in detail in the EPA publication "Energy Conservation in Municipal Wastewater Treatment," previously cited. This publication can be used by utility managers to better understand the energy requirements of their specific facility operation.

How Energy Is Used

How energy is used and at what rate, particularly electricity, has a significant affect on costs. For example, electrical energy is measured and charged based on both quantity and demand. The quantity of power used is measured in kilowatt-hours (Kwh) and electric utilites typically charge for this consumption on a unit basis. Electric utilities also charge for the peak power or demand, measured as kilowatts (KW), used by a consumer. Peak demand may only occur for 10-30 minutes a month. But the charge is assessed because sufficient generating capacity must be provided to meet these short-term peaks. Electric utilities use time-of-day rates for both quantity and demand to help distribute energy usage more evenly and reduce the need for excess capacity. Electric utilities also charge based on efficiency of the treatment equipment consuming the power. Efficiency is based on a power factor which measures the difference between actual demand and apparent demand. All three charges; quantity, peak demand and power factors can be controlled by energy conservation options.

APPROACH TO PERFORMING AN ENERGY AUDIT

A systematic approach should be followed to assess energy usage, identify and evaluate energy conservation options and implement an energy management plan.

An energy audit is carried out in the following five steps:

- develop baseline information on energy consumption and costs;
- conduct an on-site facility survey;
- identify alternative energy conservation measures;
- perform an economic analysis of each alternative; and
- develop an energy management plan.

These five steps are depicted graphically in Exhibit 3 and described in greater detail in the following sections.

Develop An Energy Use Baseline

The initial step in conducting an energy audit is to develop sufficient baseline information to evaluate possible conservation alternatives. This includes data about the type of energy used, costs, design conditions and operating procedures.

To develop the baseline, the following basic data should be gathered in preparation for the on-site review:

- energy consumption and its cost for one or more previous years, including electric utility billing records, internal electric metering records available, and records of purchased fuels. To the extent possible, energy consumption should be determined by unit process. Exhibit 4 is a form that can be used for collecting and summarizing consumption and cost data.

- utility rate schedules to determine if the utility is obtaining the best rates available or if modifications could be made to obtain a better rate. Utility representatives should be contacted for information about future rate changes that will offer energy management alternatives. These changes might include changes in demand metering equipment policies or changes in time-of-day rate schedules.

- design data, including original plans and specifications, equipment manuals, and as-built drawings, to determine the accuracy of equipment specifications and electrical ratings.

- operating and maintenance logs, to evaluate how equipment is being operated and maintained and how its performance might be improved.

- water and sewer billing records, to determine the amount of extraneous flow that is reaching the treatment facility. This can significantly increase energy consumption.

From the available data, energy consumption profiles should be determined. They can be developed directly from metering records or estimated using equipment ratings multiplied by overall average running times and load factors. Profiles should be developed:

- by fuel type (electricity, gas, fuel oil, wood);

- by unit process (pumping, primary treatment, secondary treatment, sludge treatment, sludge disposal, building energy); and

- by performance indicators (flow, pounds of BOD removed, pounds of dry solid removed).

ENERGY AUDIT METHODOLOGY

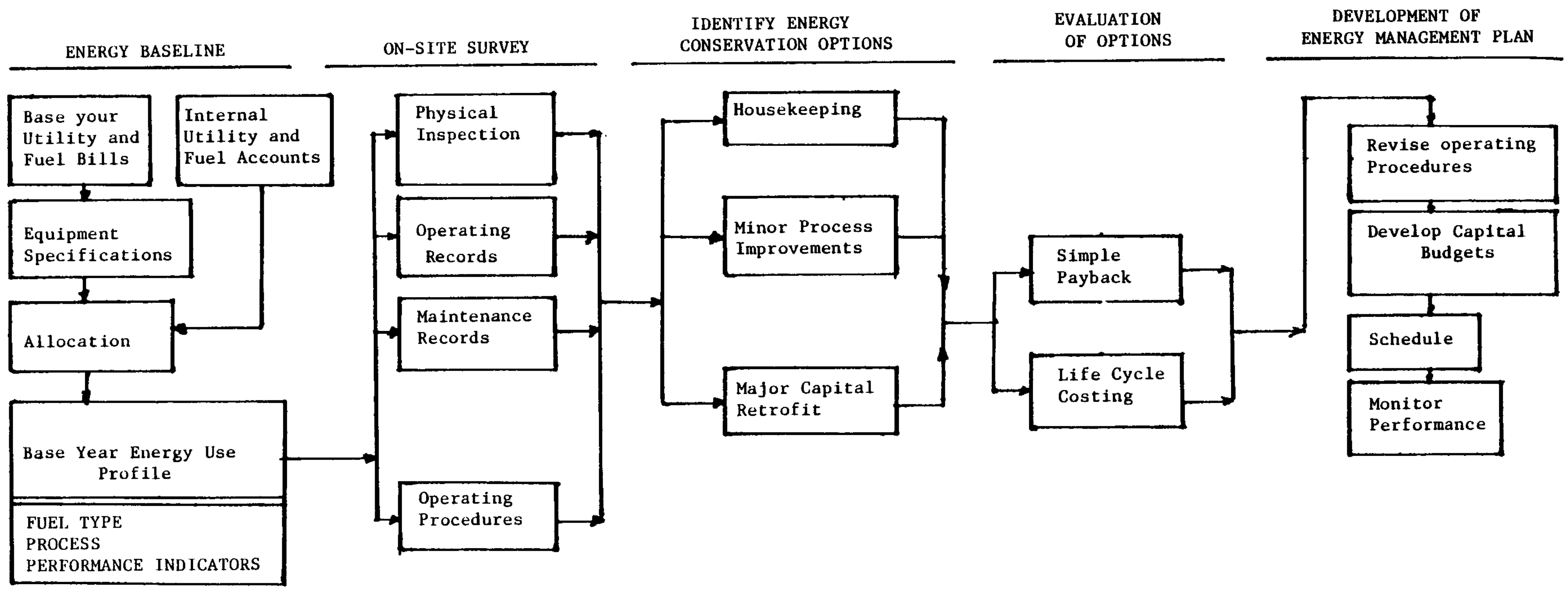


EXHIBIT 3

ENERGY DATA FORM

YEAR ________	ELECTRICITY					GAS		OIL		OTHER		TOTAL
Time of Day or Unit Process	KWH	$	KW	$	TOTAL $	THERMS	$	GAL	$	UNITS	$	TOTAL $
TOTAL												

A typical energy profile is shown in Exhibit 5. Daily operating records should be compared to utility bills to determine the relationship between the treatment facility's energy usage and the electric utility's peak demand in the operation of various unit processes.

Conduct On-Site Facility Survey

The next step in evaluating energy conservation options is to conduct a physical survey of the facility. During this survey, the following activities should be performed:

- review operating procedures for each unit process including startup procedures, equipment cycling, operations sequencing, energy recovery capabilities, and process operations efficiency.

- inspect equipment and review maintenance records to determine current state of repair including lubrication, alignment, replacement of worn parts, flow impairment, proper instrument calibration, and leaks;

- observe building energy systems and their use including lighting, heating, and cooling; and

- review process flexibility with chief operators to identify opportunities to shift process operations without impairing treatment efficiency.

Identify Alternative Energy Conservation Measures

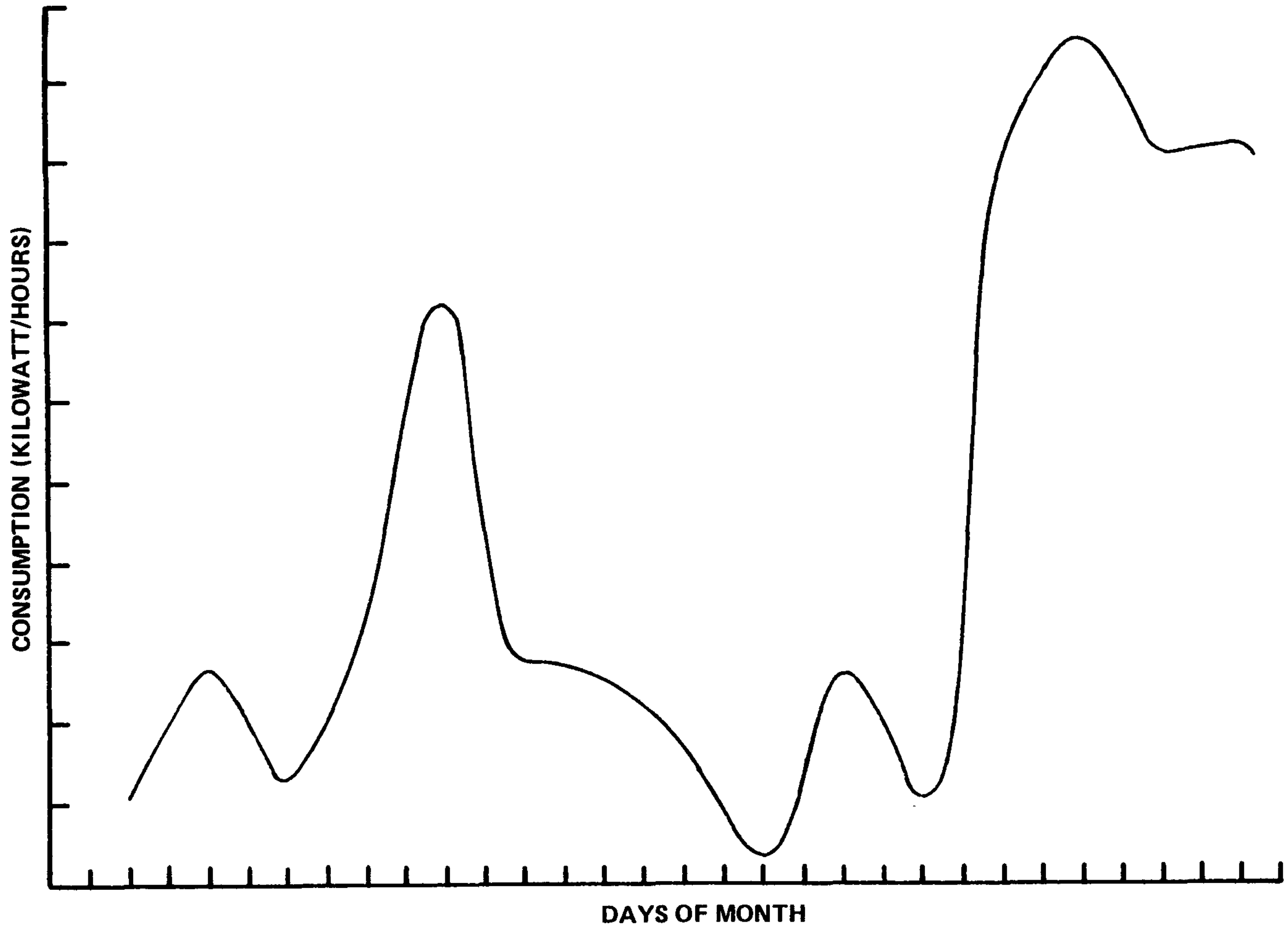
Based on the profiles of energy use and costs and the physical survey, energy conservation measures should be developed. Generally, conservation measures are grouped into three categories:

- Housekeeping - These measures can be implemented immediately by modifying operations or operating procedures with no special outlay. This could include such techniques as shutting off equipment when not needed for operations, reducing equipment cycling to improve its operating efficiencies, changing operation sequences to reduce electricity demand, adjusting equipment to improve its efficiency, fine-tuning process controls, reducing unnecessary lighting, reducing thermostat settings, and improving maintenance.

- Minor Process Improvements - These require minor capital investment with a short payback period generally financed from current maintenance budgets. They usually have little impact on process operations. This would include such techniques as installing smaller pump impellers, installing timers to cycle operations automatically, installing capacitors to improve the power factor, and using digester gas for heat treatment.

EXHIBIT 5

TYPICAL ENERGY USE PROFILE[1]



1 Variations may be caused by increased flows, due to infiltration/in flow, or cycling of equipment for various process operations.

- Major Capital Retrofit - These require major capital investment and may affect process operations. These include converting to filter press dewatering to increase solids content and reduce energy requirements, providing solar heating equipment, converting to anaerobic digestion, or installing variable speed controls.

To help identify alternative energy conservation techniques, a series of energy diagnostic checklists is provided at the end of this chapter. The checklists also identify available reference material for more detailed information on wastewater utility energy conservation.

Perform An Economic Analysis Of Alternatives

For each energy conservation alternative, an economic analysis should be performed to justify the cost of its implementation. The detail required depends on the type of alternative. For example, housekeeping alternatives are almost always economically justified even though the energy savings may be difficult to quantify. For minor process improvements, a simple payback period analysis which identifies the number of years required to recover initial costs is normally sufficient. Simple payback period is expressed as:

$$\text{Payback period (years)} = \frac{\text{Initial investment } (\$)}{\text{Annual savings } (\$/\text{yr})}$$

This analysis is performed in the following steps:

- estimate the alternative's reduction in energy consumption;
- estimate the alternative's cost impact by reducing demand surges or peaks;
- estimate total impact, if any, of power factor penalties;
- estimate any resulting increase or decrease in operation and maintenance cost;
- estimate total annual cost savings;
- estimate initial capital investment, including equipment and installation; and
- compute the simple payback period.

Simple payback is a quick and easy comparison technique but its limitations should be kept in mind. It does not distinguish between alternatives with different useful lives. Nor does it consider the value of money over time, the impact of inflation, or the fact that annual energy costs are increasing at a rate faster than capital costs.

For major capital alternatives, a more detailed, life-cycle cost analysis should be performed. This analysis considers the initial capital investment of the alternative, the useful life of the equipment involved, the cost to maintain the equipment, and the annual energy savings over the useful life. Life-cycle costing is similar to the cost-effectiveness analysis required for comparison of alternatives in 201 facilities planning. Essentially, if the present value of the annual savings is greater than the present value of the alternative's cost, it is economically justified.

Additional information on conducting detailed economic analysis of energy conservation options is contained in "Life Cycle Costing Emphasizing Energy Conservation," by the Energy Research and Development Administration, (Department of Energy), May 1977.

Based on the economic analysis, energy conservation options should be ranked according to cost-effectiveness and implementability.

Develop An Energy Management Plan

An energy management plan should be developed to ensure proper implementation of the energy conservation options chosen as a result of the evaluation. The plan includes the following activities:

- planning;
- implementing; and
- monitoring.

Planning includes revising operations and maintenance procedures where necessary to implement housekeeping alternatives, developing purchase/installation specifications or work orders for minor process improvements, and developing capital budget documentation to support major capital improvements.

Implementing involves assigning of responsibility to individuals who have sufficient authority to allocate resources, resolve conflicts, and establish schedules. Overall implementation schedules should consider the budget approval process, design or procurement requirements, and installation requirements. Improvements should be scheduled to minimize their impact on facility operations.

Monitoring requires the establishment of performance targets by energy type, by process, and for the facility as a whole to track the program. These should be based on the baseline energy profiles. Performance targets should be evaluated on a periodic basis (e.g., monthly based on utility billing) to assess whether energy consumption is consistent with the energy management plan. The targets should be revised as the energy conservation options are brought on line. Exhibit 6 illustrates the type of management reporting form that can be used.

EXHIBIT 6

MONTHLY ENERGY REPORT

FORM 4

FACILITY OR OPERATING UNIT.	MONTH.

		ELECTRIC	GAS	OIL	OTHER	TOTAL
USAGE	USAGE (YTD)*					
	BASE YEAR TO DATE					
	PERCENT ABOVE (BELOW) BASE YEAR					
COST	COST (YTD) - DOLLARS					
	BASE YEAR COST (YTD)					
	PERCENT ABOVE (BELOW) BASE YEAR					
PRICE	COST PER MMBTU** (CURRENT MONTH)					
	BASE YEAR COST					
	PERCENT ABOVE (BELOW) BASE YEAR					
PERF. INDICAT.	USAGE PER 1000 GALLONS					
	BASE YEAR USAGE PER 1000 GALLONS					
	PERCENT ABOVE (BELOW) BASE YEAR					
	COST PER 1000 GALLONS					
	BASE YEAR COST PER 1000 GALLONS					
	PERCENT ABOVE (BELOW) BASE YEAR					

*YEAR-TO-DATE
**MILLION BTU

DIAGNOSTIC CHECKLIST FOR ENERGY MANAGEMENT OF WASTEWATER FACILITIES

The following energy management diagnostic checklists are provided to assist utility personnel in performing an in-house review of energy consumption around the utility and evaluate energy conservation options. The checklist is designed for use after the utility has developed its baseline profiles, or has set targets for energy use.

The checklist is organized as follows:

- Column 1 - identifies process phase;
- Column 2 - identifies typical energy uses for each process phase;
- Column 3 - provides methods to identify energy inefficiencies;
- Column 4 - identifies potential conservation measures;
- Column 5 - identifies cost and benefit considerations;
- Column 6 - identifies potential adverse impacts on utility operations; and
- Column 7 - identifies selected references for more detailed information. The list of references is attached at the end of the checklist.

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
I. PUMPING: CONVEYANCE AND PRIMARY SYSTEMS	Fuel for engine-driven pumps.	1. Poor performance(e.g. hard-starting, back-firing,etc.) or excessive fuel consumption.	1. Tuneup.	1. <u>Costs</u>:maintenance. <u>Savings</u>: reduced fuel consumption.	1. None	
		2. Not using digester gas, if available.	2. Substitute digester gas for purchased fuel.	2. <u>Cost</u>:equipment reconfiguration. <u>Savings</u>: purchased fuel.	2. May need standby operations.	
		3. Operating at less than 50% of design load (low flow, excessive discharge throtting, etc.).	3A. Shut down unnecessary pumps.	3A. <u>Costs</u>:none. <u>Savings:</u> energy.	3A. Inadequate pumping if pumps remain off during high influent flows.	Vendor manuals
			B. Install variable speed controller.	B. <u>Costs</u>:equipment.<u>Savings</u>: energy.	B. Inadequate pumping of setpoints are improper.	
			C. Replace with smaller high efficiency pump.	C. <u>Costs</u>:equipment.<u>Savings</u>: energy.	C. Inadequate pumping if pump is undersized.	
		4. Large reactive load (power factor 0.8 or less).	4. Install capacitors to increase power factor, or variable speed driver or synchronous motors.	4. <u>Cost</u>: capacitor as a function of electrical size versus reactive load savings.	4. None	
		5. Excessive electrical demand.	5. Install demand limiter	5. <u>Cost</u>: installation and operation. <u>Savings</u>:demand charges.	5. Inability to keep up with incoming flow. Must be able to override demand limiter.	

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
I. PUMPING: CONVEYANCE AND PRIMARY SYSTEMS	Electrical Power for Motors	1. Rapid Cycling	1A. Employ sequential starting.	1A. Costs:none Savings:reduced demand and energy.	1A. Overflow or underflow unless automated.	Reference 1
			B. Change liquid level controller setpoints.	B. Costs:corrective maintenance Savings:reduced demand.	B. None	
			C. Operate equalization basins or increase capacity and operate pumps to shift some load to off-peak period.	C. Costs:storage. Savings:peak period electrical consumption.	C. Backshift labor	
		2. Excessive power/current drawn (compared to design) for flow produced, or inadequate flow.	2A. Investigate blockage, impeller or bearing wear, packing tightness, etc.	2A. Costs:repair. Savings:improved performance.	2A. None	Vendor manuals, acceptance tests, reference 2
			B. Clean basin, piping, filters, etc.	B. Costs:maintenance. Savings:energy.	B. None	
			C. Redesign piping to to reduce head'loss.	C. Costs:ripout and replacement. Savings: energy.	C. Process interruption.	Reference 1

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
II. PRELIMINARY TREATMENT	Electrical power for comminutors and/or screens.	1. Either excessive buildup of debris or excessive debris removal.	1. Adjust timing of screenings removal.	1. Costs: motor speed change. Savings: electrical power.	1. None	1. Reference 1
	Electric power for grit removal.	2. Efforts to attain "clean" grit through washing.	2. Reduce washings to capture maximum grit.	2. Costs: none. Savings: Electric Energy.	2. Improper control.	2. Reference 2
	Fuel for grit disposal.	3. Burning for disposal then hauling.	3. Bury on site.	3. Cost: land disposal. Savings: fuel	3. Inadequate odor control.	3. Reference 2
III. PRIMARY TREATMENT	Electric power for sludge and skimings collection and removal.	1. Overpumping of sludge from settling basins.	1. Reduce flow by manual or auto pump shutdown.	1. Cost: reduction device. Savings: Electric Energy.	1. Inadequate pumping.	

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
III. SECONDARY/ TRICKLING FILTERS	Electrical power for recirculation pumping (trickling filters).	1. See Section I on pumping.	1. See Section I.	1. See Section I.	1. See Section I.	1. See Section I.
		2. Excessive recircula- flow beyond process requirements.	2. Reduce recirculation flow automatically or manually.	2. Cost: flow reduction device. Savings: Electric Energy.	2. Inadequate recirculation during periods of high flow.	2. Reference 1
		3. Using stone media.	3. Install synthetic media to improve treatment with less recirculation.	3. Cost: new media purchase and old media disposal. Savings: improved organic reduction and reduced processing energy.	3. Process interruption.	
SECONDARY/ ROTATING BIOLOGICAL CONTRACTORS (RBC)	Electrical power for media rotation.	1. Unncessary number of units in use during low flow periods.	1A. Reduce the number of RBCs in use manually or automatically.	1A. Cost: none or auto device. Savings: electrical power.	1A. Inadequate treatment if additional units not started when flow/solids increase.	
			B. Reduce the speed of operating RBCs.	B. Cost: device installation. Savings: electrical power.	B. Inadequate treatment if speed not increased as flow/solids increase.	

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
III. SECONDARY/RBC		2. Using motor-driven contactors.	2. Convert to diffused air-driven contactors.	2. Cost:retrofit installation plus fan power. Savings: electric power.	2. Insufficient O_2 transfer to support biological activity.	1.Reference 1.
SECONDARY/ ACTIVITATED SLUDGE	Electrical power for blowers.	1. No bubbles exiting diffusers or low DO in effluent.	1. Clear Blockage(clean diffusers or filters).	1. Cost:maintenance. Savings: increased performance.	1. None.	
		2. Unnecessary number of units in operation during low flow	2A. Reduce the number of units operating.	2A. Cost: none or device installation. Savings: electrical power.	2A. Inadequate treatment if flow increases.	
			B. Throttle suction value of remaining units.	B. Cost:none. Savings: electrical power.	B. Blower surge.	Reference 1
			C. Install variable speed controllers.	C. Cost:controller retrofit and operation. Savings: electrical power.	C. Inadequate treatment if underdesigned.	
		3. Suboptimal BOD removal.	3. Optimize process parameters with respect to treatment and energy performance.	3A. Cost: employee training and increased control measures. Savings: reduced processing energy. Benefits: greater compliance.	3A. Inadequate organizes removal.	3A. Reference 1
		4. High electric demand charges.	4A. Reduce surges from startup via staging, or starting in low-load periods (nights)	4. Costs:none. Savings: Demand Charge		

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
III. SECONDARY/ ACTIVITATED SLUDGE			4B. Install timeclocks on aerators for diurnal variations.	4B. Cost: equipment installation and operation. Savings: Demand Charge.	4B. Inadequate oxygen transfer.	4B. Reference 4
		5. Excessive air for treatment requirements	5A. Reduce air distribution during low flow periods.	5A. Cost: flow reduction Savings: power.	5A Inadequate if air not restored during high flow.	5A. Reference 1.
			B. Redesign, relocate system components for more efficient oxygen transfer.	B. Cost: system design, retrofit, operation. Savings: improved performance and reduced electrical power.	B. Inadequate O_2 if designed improperly, (inadequate mixing, incomplete BOD removal.	B. References 1 & & 3
		6. Excessive nitrification.	6. Reduce Sludge Retention Time.	6. Cost: none. Savings: Process energy.	6. Inadequate organic removal if overcorrected.	6. Reference 7.
	Electrical power for mechanical aerators.	1. Excessive air for treatment requirements.	1A. Reduce number or speed of aerators during low flow.	1A. Cost: none. Savings: electrical.	1A-B. Inadequate O_2 transfer or or mixing.	1A-D. Reference 1.
		2. Water level too high in mechanical aerator.				
		3. High electric demand charges.	3. Schedule startups of mixers and other units to avoid coincident surges.	3. Costs: none. Savings: reduced electric demand charges.		

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
III. SECONDARY/ ACTIVITATED SLUDGE			B. Reduce speed of operating aerators.	B. Cost:speed control device. Savings: electrical power.		
			C. Convert to bubble diffuser aeration.	C. Cost:retrofit and operation. Savings: electrical power.		
	Electrical power for oxygen generation.	1. Excess O_2 consumption from open tanks.	1A. Install tank covers and institute automatic feed control.	1A. Cost: tank fabrication and feed control. Savings: electrical power.	1A. Either inadequate O_2 (inadequate transfer) or excess O_2 (safety hazard) if designed/operated improperly.	1A. Reference 1
			B. Convert to air-blown system.	B. Cost: new system retrofit and operation. Savings: electrical power for O_2.	B. Inadequate O_2 transfer or mixing.	
			C. Install weir to automatically control liquid level.	C. Cost:weir installation. Savings: electrical power.		

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
III. SECONDARY/ ACTIVITATED SLUDGE		2. Purchasing O_2 (for plants larger than C. 2 Mgd).	2A. Generate O_2 on-site during off-peak hours (provide adequate storage).	2A. Cost: O_2 generator (pressure swing absorption or cryogenic). Benefits: power. Savings: purchased O_2	2A. Safety hazards backup O_2 if unit fails.	2. Reference 1
			B. Convert to air-blown system.	B. Cost: new system retrofit and operation. Savings: purchased O_2.	B. Inadequate oxygen transfer.	2. Reference 1

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS &	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
IV. SLUDGE/ DIGESTION	Electrical power for blowers and mechanical aeration in aerobic digestion.	1A. See Section I on pumping.	1A. See Section I.	1A. See Section I.	1A. See Section I.	1A. See Section I
		B. See Section III on activated sludge.	B. See Section III	B. See Section III.	B. See Section III.	1. See Section III
		C. Foaming (overaeration), excess DO.	C. Reduce aeration.	C. Cost:none. Savings: electrical power.	C. Inadequate O_2 transfer or mixing.	1. Reference 6
		2. Using batch process loading and decanting.	2. Operate feeder pumps continuously to minimize shocks.	2. Costs:electrical power. Savings:reduced energy for sludge handling and disposal.	2. None.	2. Reference 6
		3. Inadequate volatile solids loading (much less than design).	3. Increase volatile solids concentration (decrease SRT).	3. Cost:none. Savings:reduced process energy.	3. Excess VS loading or low DO.	3. Reference 6
		4. Excess VS or low DO.	4. Increase SRT.	4. Costs:none. Savings:reduced pumping power. Benefits:improved process efficiency.	4. Overcorrection	4. Reference 6
		5. Using extended aeration.	5A. Convert to simple activated sludge.	5A. Costs:retrofit and operating labor costs. Savings: energy from aeration.	5A. Improper design.	5A. Reference 6

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
IV. SLUDGE/ DIGESTION			5B. Convert to anaerobic digestion with energy recovery.	5B. <u>Cost</u>:Process conversion and operation. <u>Savings</u>: electrical power and conventional fuel purchases.	5B. Process interruption. Noncompliance if improperly designed or operated.	5B. Reference 5
	Raising temperature for anaerobic digestor.	1. Temperature $>98^{o}F$ (mesophilic range).	1. Reduce temperature by: A. reducing fuel combustion. B. reducing digestor gas firing temperature. C. reducing waste heat input.	1A. <u>Costs</u>:none. <u>Savings</u>:Conventional fuel. B&C. <u>Costs</u>: opportunity costs of waste heat recovery. <u>Savings</u>: may use in other plant processes.	1. Slowed reaction rates if temperature drops below $85^{o}F$.	1. Reference 5
		2. Widely varying digester temperatures or vs. contrations.	2. Feed sludge slowly and continuously rather than in large batches.	2. <u>Costs</u>:none. <u>Savings</u>:heat input. Benefits:more complete sludge processing.	2. None	2. Reference 6

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
IV. SLUDGE/ DIGESTION		3. Improper sludge loading.	3. Restore volatile solids (VS) concentrate to 0.03 to 0.1 lb VS per cubic foot per day.	3. Costs:pumping power. Savings: heat input.	3. None	3. Reference 6
		4. Leaking seals, cracks in walls, etc.	4. Repair	4. Cost:repair labor and supplies. Savings:heat.	4. None	4. Reference 6
		5. Inefficient heat transfer in digester heat exchanger.	5. Clean surfaces.	5. Cost:maintenance. Savings: heat input.	5. None	5. Reference 2
		6. Uninsulated tank roof.	6. Insulate with thickness recommended for region.	6. Cost:materials and installation. Savings: heat input.	6. None	
		7. Underinsulated tank walls (cold climate)	7. Add insulation to achieve thickness recommended for region.	7. Cost:materials and installation. Savings: heat input.	7. None	
		8. Using low rate digestion.	8. Convert to high rate digestion (0.3 lb vs cubic foot per day)	8. Cost:conversion and operation cost. Savings:process energy.	8. Inadequate processing if designed or operated improperly.	8. Reference 6
		9. Flaring or otherwise not recovering digester gas.	9. Recover digester gas and use for: A. digester heating B. sale C. electricity generation D. plant heating	9. Cost:equipment construction and operation. Savings:conventional fuel.	9. Need for supplemental energy if improperly designed.	9. Reference 5

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
V. SLUDGE/TREATMENT & CONDITIONING	Fuel for heat treatment (thermal conditioning	1. High temperatures relative to design.	1. Reduce steam consumption (fuel firing rate) to reduce temperatures to lowest practical.	1. Costs: None. Savings: Fuel	1. Incomplete conditioning if temperatures reduced too much.	1. Reference 6
		2. Excess air greater than design.	2A. Shutdown unnecessary blowers. 2B. Throttle flow.	2. Costs: None. Savings: Electrical power.	2. Incomplete conditioning if air reduced too much.	2. Reference 6
		3. Operating batch process with many start-ups and shutdowns.	3. Operate continuous or semi-continuous process.	3. Costs: Back-shift labor. Savings: Conventional fuel for startup.	3. None	3. Reference 6
		4. Using afterburner to destroy odors.	4. Discharge off gases through secondary treatment tanks.	4. Costs: Equipment reconfiguration. Savings: Conventional fuel.	4. Air quality constraints.	4. Reference 4
		5. Not using waste heat.	5A. Install economizer to pre-dry sludge. 5B. Recover waste heat to supplement building or process heat.	5A&B. Costs: Equipment installation. Savings: Conventional fuel.	5A&B. None	5. Reference 6
		6. Not using treated sludge to supplement conventional fuel.	6. Fire sludge for part of the energy requirements.	6. Costs: Sludge handling and conveying. Savings: Conventional fuel.	6. Air quality constraints.	6. Reference 6
		7. Not using lower net energy process.	7. Convert to anaerobic digestion with heat recovery.	7. Costs: Equipment design, and construction, and operation. Savings: Conventional fuel.	7. Inadequate processing if designed or operated improperly.	7. Reference 6

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
V. SLUDGE/TREATMENT & CONDITIONING (Cont.)	Pumping during thickening.	1. See section I on pumping. 2. See section II on sedimentation.				
		3. Large number of fre- quent) dewaterings. 4. Using froth flotation year round.	3A. Reduce number of dewatering periods to minimum practical. 3B. Thicken in primary sedimentation tanks.	3. Costs: Storage Savings: Electrical power. 3B. Costs: None. Savings: Electric power.	3A&B. Incomplete dewatering if not monitored.	3. References 2&4
	Fan power for vacuum filtration.	1. Low sludge content in fuel.	1. Increase sludge concentration.	1. Costs: Upstream Costs. Benefits: greater cake formation for the energy used.	1. Longer times, increased chemical usage.	1. Reference 6
		2. Suboptimal machine variables.	2. Restore drum speed, submergence depth, and vacuum to design conditions.	2. Costs: Maintenance. Benefits: greater cake formation for the energy used.	2. None	2. Reference 7
		3. Plugged filter media.	3A. Clean filter. 3B. Replace filter with new media.	3A. Costs: Maintenance. Savings: Electrical power. 3B. Costs: Filter. Savings: Electrical power.	3. None	3. Reference 4
		4. Not using low energy processes.	4. Convert to drying bed or belt process.	4. Costs: Equipment configuration and operation. Savings: Electrical power.	4. Incomplete dewatering.	4. Reference 1
	Electrical	1. Excessive water in the sludge cuter.	1A. Reduce conveyor speed. 1B. Increase bowl speed.	1A. Costs: None 1B. Costs: Electrical power. 1A&B. Benefits: Greater solids recovery and dryer cake requiring less energy in subsequent process phases.	1A&B. Low solids recovery if overcorrected.	1. Reference 6

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
V. SLUDGE/TREATMENT & CONDITIONING (Cont.)	Electrical power for filter press.	1. Excessive blinding.	1A. Precoat with incinerator ash or polymer.	1A. Costs: Chemicals. Savings: Dryer solids requiring less subsequent energy.	1A. None	1A. Reference 6
			1B. Replace with monofilament media.	1B. Costs: Media replacement. Savings: Greater cake recovery and dryer solids.	1B. Improper design	1B. Reference 6

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
VI. SLUDGE/DISPOSAL	1. Pilot fuel for incineration.	1. Excessive use (10 to 20% of total Btus) or high temperature.	1A. Reduce the amount used for flame stabilization.	1A. Costs: none. Savings: purchased fuel.	1A. Temperatures too low to destroy odors, or unstable flame.	1. Reference 1
			1B. Install economizer to predry sludge.	1B. Cost: design, procurement, and installation. Savings: fuel.	1B. None	
			1C. Go to semi-continuous operation. Extinguish pilot flame during extended shutdown.	1C. Cost: additional supervisory labor.	1C. Must ensure gas flow completely shutoff to prevent subsequent explosion.	1C. Reference 1
	2. Fan power for incineration.	1. Excess air over that required for complete combustion (high O_2 concentration in stack).	1. Reduce fan power (e.g. secure one unit).	1. Costs: none. Savings: fan power.	1. Inadequate air flow.	Vendor manual, acceptance tests.
			2. Install automatic O_2 analysis to control air flow.	2. Costs: equipment and running expenses. Savings: fan power.	2. None	
	3. Electrical power for pollution control equipment for incineration.	1. Excessive pressure drop or current (e.g. precipitator) compared to design.	1. Clean surfaces.	1. Costs: maintainance. Savings: electrical power. Benefits: improved performance.	1. None.	Vendor manuals

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
VI. SLUDGE/DISPOSAL			2. Reduce induced draft fan power.	2. Cost:none. Savings:electrical power.	2. Inadequate pollutant removal rates.	
	4. Incineration heat losses up the stack or into cooling water.	1. No recovery.	1. Consider recovery and use for building space heating or process.	1. Costs:design, procurement, installation, and operation. Savings:purchased fuel or electricity.	1. Inadequate space conditioning or gas utilization if poorly designed.	Acceptance tests
		2. Not integrated with other plant chemical processes requiring heat/steam.	2. Consider lime recalcining recovery, activated carbon regeneration, or ammonia stripping with steam.	2. Costs:equipment, installation and operation. Savings:purchased fuels, steam or chemicals.	2. Inadequate chemical recovery.	2. Reference 5
		3. Not integrated with anaerobic digestion or heat treatment.	3A. Consider heat recovery to sustain anaerobic digestion or heat treatment with only supplemental fuel purchases.	3A. Costs:equipment, installation. Savings:purchased fuel.	3A. Inadequate processing.	3. References 1 & 5
			3B. Consider converting to composting.	3B. Costs:equipment. Benefits:Revenues from compost sales and savings from reduced ash hauling and pollution control expense.	3B. Unsaleable products.	

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
VI. SLUDGE/DISPOSAL	Transportation to landfill	1. Excessive number of trips.	1A. Run only full loads. 1B. Concentrate/dewater solids further.	1A. Costs: None. Savings: Fuel. 1B. Costs: Process energy. Savings: Transportation fuel.	1. None	Reference 1
		2. Long hauls.	2. Review shorter hauls (e.g. to nearby parks or farms).	2. Costs: None. Savings: Fuel.	2. Trace elements (e.g. heavy metals) may make this option impractical.	
		3. Poor vehicle fuel mileage.	3A. Maintain vehicles in good running condition. 3B. Replace old small units with new efficient large models.	3A. Costs: Maintenance. Savings: Fuel. 3B. Costs: Vehicle replacement. Savings: Fuel.	3. None	
		4. Truck transport to adjacent landfill.	4. Install pipeline if distance is short and flow is continuous.	4. Costs: Pipeline design, laying & operation. Savings: Fuel.	4. None	Reference 8

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
VII. BUILDINGS	1. Lighting.	1. Excess lighting levels	1A. Turn off lights in unoccupied spaces and at end of working day.	1A&B. Costs: none. Savings: power.	1A. None	Reference 4
			1B. Reduce levels by removing bulbs.		1B. Inadequate lighting.	
			1C. Clean bulbs and fixtures to minimize the need for additional bulbs.	1C. Costs: Maintenance. Savings: electrical power.	1C. None	
		2. Incandescent or other inefficient bulbs.	2. Replace outdoor lighting with sodium vapor, indoor with high efficiency fluorescent.	2. Costs: light Savings: electrical.	2. None	Reference 4
		1. Poor housekeeping (open doors, extended air conditioning).	1A. Indoctrinate plant staff. 1B. Zone building with thermostat.	1. Cost: staff training & equipment. Savings: building energy.	1. None	Reference 4
	2. Space conditioning.	2. Not taking advantage of passive solar.	2. Retrofit passive solar applications (various)	2. Cost: retrofit. Savings: purchased fuel.	2. None	
		3. Excessive amount of ventilation.	3. Reduce air flow to minimum practical.	3. Cost: none. Savings: purchased fuel and recovered energy.	3. Inadequate ventilation.	Reference 4
		4. Not taking advantage of waste heat.	4A. Supplement building heat with incinerator or thermal conditioning waste heat.	4A. Cost: equipment reconfiguration. Savings: conventional fuel.	4. None	Reference 4

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
VII. BUILDINGS			4B. If process plant already uses steam, install steam absorption chillers.	4B. Cost: equipment installation operation. Savings: electricity.		
		5. Firing conventional fuels.	5A. Use water-to-air or water-to-water heat pumps on plant effluent.	5A. Cost: equipment installation and operation. Savings: conventional fuel.	5. Process suboptimization.	Reference 1
			5B. Recover process plant energy (digester gas, sludge firing, engine jacket cooling, etc.)	5B. Total cost of energy recovery versus displacement of conventional fuels.		
		1. Firing conventional fuels or using electricity.	1. Insulate hot water heat and piping.	1. Cost: insulation. Savings: energy.	1. None	
			2. Recover heat from plant processes (engine cooling water, digester heat, etc.)	2. Cost: system design installation & operation. Savings: conventional fuel/electricity.	2. Improper temperatures.	
			3. Install solar panels.	3. Cost: system installation, operation & maintenance. Savings: conventional fuel/eletricity.	3. Improper temperatures.	

PROCESS/STEP	ENERGY USES	INDICATIONS OF ENERGY INEFFICIENCIES	POTENTIAL CONSERVATION MEASURES	COSTS & SAVINGS	POTENTIAL IMPACT ON OPERATIONS	REFERENCES
VIII. MAINTENANCE EQUIPMENT & INSTRUMENTATION	-	1. Overdue calibrations or other tests.	1. Perform checks as required. Repair as necessary.	1&2. Costs: Maintenance. Savings: Identify improperly functioning equipment.	1. None	
		2. Failed meters and gauges.	2. Repair		2. None	
		3. Informal maintenance practices.	3. Install formal preventive maintenance.	3. Costs: Maintenance labor and meterial. Savings: Improved equipment performance.	3. None	
IX. ELECTRIC LOAD MANAGEMENT	Demand component of electric billing	1. Excessive demand charges in relation to rated loads of pumps, blowers, etc.	1. a) Overall start/stop scheduling for pumps, blowers, mixers, etc. to avoid coincident surges. b) Deferral of influent pumping via equalization basins to avoid peak demand periods. c) Deferral of solids processing until off-peak periods.	1. Costs: None Savings: reduced demand charges.	1. None	

REFERENCES

1. Aeration in Wastewater Treatment Plants, MOP-5, Water Pollution Control Federation, 1971.

2. Energy Conservation in the Design and Operation of Wastewater Treatment Facilities, Water Pollution Control Federation, 1981.

3. Energy Conservation in Municipal Wastewater Treatment, U.S. EPA, 430/ 9-77-011, March 1978.

4. Management of Small to Medium-Sized Treatment Plants, U.S. EPA, 430/ 9-79-013.

5. Operation of Wastewater Treatment Plants, MOP-11, Water Pollution Control Federation, 1975.

6. "Processes--Not Products--Biggest Energy Saving Factors," Water and Sewage Works, November 1980.

7. "Selecting Pipelines to Achieve Effective Energy Conservation," A. Reid, Water and Sewage Works, November 1980.

8. Wastewater Treatment Plant Design, MOP-8, Water Pollution Control Federation, 1977.

9. Energy Conservation at Wastewater Treatment Plants, a Special Publication of the Technical Practice Committee, SPCF, 1980.

10. Life Cycle Costing Emphasizing Energy Conservation, by the Energy Research and Development Administration, (Department of Energy), May 1977.

11. Proceedings of the U.S Department of Energy, Energy Optimization of Water and Wastewater Management for Municipal and Industrial Applications Conference, 1979.

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