Energy Efficient Alternatives for the Fortuna Wastewater Treatment Facility

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1 Introduction

In 2001, California was rudely awakened to the importance of energy conservation. The "California energy crisis" rippled across the nation as the state of California was struggling to meet energy demands and rising energy prices. Rolling blackouts and outlandish electricity prices forced many businesses to raise prices, close down or suffer the consequences. The energy crisis left the state virtually bankrupt and long-term effects will be felt for the next several decades.

With the looming effects of the energy crisis many Californians are rising to the challenge, faced with increasing electricity prices the state has dramatically changed it's practices related to energy conservation. The state has launched intensive campaigns to promote energy conservation in all aspects of everyday life. The intensive energy usage of wastewater treatment facilities has been identified by the state as a critical area for local municipalities to implement energy conservation measures.

Wastewater treatment facilities throughout the country are treating industrial and domestic sewage to maintain the quality of aquifers, rivers, lakes, streams and oceans. These facilities are often expensive to operate and extremely energy intensive. Typically, 35% of the energy used by a municipality is for the treatment of wastewater (EFAB 2001). In the United States, electricity usage in transport and treatment of both water and wastewater account for more than $6.5 billion dollars annually. However, it is predicted that this figure can be reduced by 15% with the implementation of energy conservation strategies (ASE 2002). In California, water and wastewater treatment accounts for 5% of the total energy consumption; as California's population continues to rise the energy required for the transport and treatment of water and wastewater will also increase. With increased energy costs conservation measures will be essential to the future success of many small communities.

The term energy conservation, used here, represents an increase in energy efficiency. The goal is to perform the same amount of work with less energy (USEPA 2002). Performing more work with less energy could lead to a significant decrease in the cost of operating wastewater treatment facilities. Energy conservation also serves to reduce air pollution associated with power generation.

Energy efficiency is an important issue in the operation and management of wastewater treatment facilities. Understanding consumption, conservation and recovery of energy in wastewater treatment is essential in determining energy conservation decisions. With increasing water quality standards many communities are faced with the difficult task of upgrading existing facilities to meet increased flows and reduce operation and maintenance costs associated with energy consumption. The objective of this study is to assess the best available energy conservation technologies for wastewater treatment and establish a decision policy for implementation of various energy conservation measures at the Fortuna facility.

2 Fortuna's Wastewater Treatment System

The City of Fortuna is a small community on the north coast of California. The wastewater treatment facility that services the community is owned and operated by the City of Fortuna. The wastewater treatment facility has a capacity of 3 million gallons per day (MGD) however, flows into the facility range from 1 MGD in the dry summer months to 5 MGD during the rainy winter months (CRWQCB 2000). The average flows into the facility have been estimated at 1.03 MGD.

The wastewater stream is treated to a secondary treatment level using the activated sludge process. The effluent from the secondary clarifier is treated with chlorine for disinfection and sulfur dioxide to dechlorinate the water prior to discharge into the Eel River. During the summer months when flows in the Eel River are lower, water from the treatment facility is discharged into a percolation pond on an exposed gravel bar. During winter months when wastewater flows exceeded the 3 MGD capacity the wastewater is diverted into two storm water holding/oxidation ponds. The water stored in the holding/oxidation ponds is treated by the activated sludge process, chlorinated, dechlorinated and discharge into the Eel River (CRWQCB 2000).

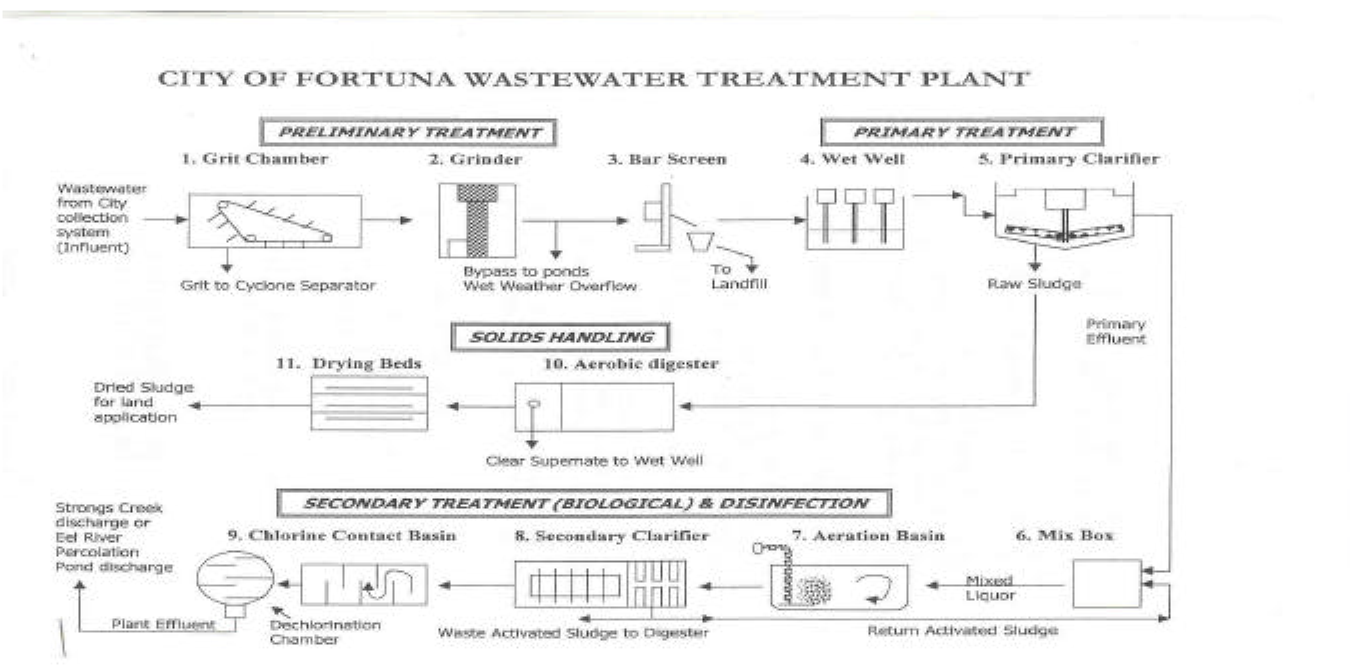

Figure 1 A schematic of the Fortuna wastewater treatment process, which describes the flow of wastewater through a network of biological, chemical and physical treatment processes.

The initial stage in the wastewater treatment process is preliminary treatment. In this stage wastewater flows into a grit chamber where the flow is reduced to settle out inorganic solids, such as; sand, gravel and eggshells. From the grit chamber the wastewater stream flows through a grinder where rotating blades cut up rages or solid material into smaller pieces smaller particle sizes improve the efficiency of the biological processes required in later stages. The bar screen removes the rags and other inorganic material not reduced in size by the grinder. The goal of this phase of the treatment process is to remove or reduce large debris from the wastewater stream (FWWTP 2003).

After preliminary treatment, the wastewater stream flows into the wet well where it is pumped up into the next stage (the remaining portion of the water stream flows hydraulically, i.e., no pumping required). The water is pumped up from the wet well into the primary clarifier where 90-95% of the settleable solids are removed (FWWTP 2003). The solids that have settled out form a sludge that is approximately 1-2% solids. The biochemical oxygen demand (BOD) is also reduced during this stage. It is predicted that 40-60% of the BOD in the influent is removed during this stage (FWWTP 2003). The primary effluent is then combined with return activated sludge in a mix box. The effluent flows out of the mix box into the aeration basin where it is aerated (combined with air), which promotes the growth of aerobic bacteria that degrades organic material. The waste stream from the aeration basin flows into the secondary clarifier where the activated sludge is settled out of solution. A portion of the settled activated sludge is then recycled back into the mix box. The water effluent flows into the chlorine contact basin for disinfection and then into a dechlorination chamber where sulfur dioxide is added to reduce the chlorine. Once this process is completed the water is then discharged into the Eel River. The remaining portion of the solids from the secondary clarifier and the solids from the primary clarifier are pumped to the aerobic digester. The aerobic digester completes the solids stabilization process. The final solids product is then pumped to drying beds where the water content is reduced by 50%. The sludge product is composted for use as a soil amendment. If the treatment facility is experiencing a large volume of sludge then polymers are added to improve coagulation and speed drying time. The final solids product is used for land application at the facility and on local farms (FWTF 2003).

3 Understanding Electricity Usage

3.1 The Electricity Bill

The energy requirements for wastewater treatment systems are increasing as water quality standards increase and communities grow. Understanding how electricity is billed and distributed is essential in determining energy efficient alternatives for wastewater treatment systems. Energy typically represents the majority of the operating costs associated with running a wastewater treatment facility. Reducing energy usage will ultimately lead to a savings both environmentally and financially (EPRI 1998).

There are two types of billing information that will appear on a utility bill. The “energy” component represents the amount of electricity supplied to the facility in kilowatt hours (kWh). This is a measure of the quantity of electricity used. The other component is the “demand”, which represents the power supplied to the facility in kilowatts (kW). Demand is measured in 15 to 30 minute intervals; the demand charge is based on the highest demand interval each month. The costs associated with transmission, distribution, nuclear decommissioning and taxes are also included in the electrical utility bill. There are also various “rate schedules” for electricity usage. Rate schedules define the price of electricity for different times of the day. During the higher demand periods, the rates are highest. During the lower demand periods the rates are lower. Summer rate schedules include a partial-peak rate for those times when energy demand is somewhere in between the high and the low demand (EPRI 1998).

3.2 Summer Rate Schedule

Table 1 Summer rate schedule

Summer	
Peak	$0.1007 / kwh
Partial Peak	$0.05131 / kwh
Off-Peak	$0.04131 / kwh
Electrical Energy Charge	$0.03986 / kwh

Table 1, shows the “summer” rate schedule for the Fortuna facility. The summer rates are in effect for the months of June through October. There are three tiers of billing for the summer usage; peak, partial-peak and off-peak, measured in kWh. The electrical energy charge represents the cost of the “demand” in kW. The peak rate is for the hours when the demand is the largest and is between 12pm to 6pm. The partial peak rate is the middle tier and is between the hours of 8^{30}am to 12pm. The last tier and the least expensive time to operate are during the off-peak billing period, which is typically, 5am to 8^{30}am and 9^{30}pm to 1am.

Utility bills for June 2002 through October 2002 were examined to determine demand and energy usage along with the costs associated with each. The average summer energy usage is 3,894.8 kWh / day.

Table 2 Summer energy usage at the Fortuna Wastewater Treatment Facility

Date	Usage (kWh)	Total Charges ($)	Peak (kWh)	Partial-Peak (kWh)	Off-Peak (kWh)	KWh/day
6 / 6 / 02 to 7 / 8 / 02	121,760	16,947.70	19,920	23,440	78,400	3,805
7 / 8 / 02 to 8 / 6 / 02	110,160	15,997.35	20,160	23,840	66,160	3,799
8 / 6 / 02 to 09 / 5 / 02	116,560	16,744.55	20,720	24,240	71,600	3,885
9 / 5 / 02 to 10 / 4 / 02	116,760	16,645.90	20,480	24,000	69,280	3,923
10 / 4 / 02 to11 / 4 / 02	125,920	17,376.22	19,760	49,480	79,680	4,062

Table 2, summarizes energy usage for the summer rate schedule. The cost portion of the table includes the demand charge; however, the demand is not listed. The Fortuna wastewater treatment facility has the highest energy requirement during the off-peak hours with the smallest usage during the peak periods. The average cost of energy usage during the summer rate period is $16,742.34 / month.

3.3 Winter Rate Schedule

Table 3 Winter rate schedule

Winter	
Partial Peak	$0.06392/kwh
Off-Peak	$0.05038/kwh
Electrical Energy Charge	$0.05209/kwh

During the winter months the electrical energy prices change. The "winter" rate schedule is listed in Table 3. The costs associated with energy usage is significantly cheaper during the winter months however, the demand charge increases. The winter rate schedule is broken down into a two-tier system. The first tier is a partial-peak rate, which, is between the hours of 12pm to 6pm. The second tier is the off-peak charge, which is between the hours of 5am to 8^{30}am and 9^{30}pm to 1am.

The winter rate schedule occurs during the months of November through May. Utility bills were examined for the months of November 2002 trough February 2003. Table 4, summarizes the electrical energy usage for November 2002 through February 2003. The energy usage during the winter is much higher with an average of 4,322 kWh/day. However, the cost of electricity during the winter months is significantly lower with an average cost of $13,949.60. The largest energy usage occurs during the off-peak hours.

Table 4 Winter energy usage at the Fortuna Wastewater Treatment Facility

Date	Usage (kWh)	Total Charges	Partial Peak (kWh)	Off Peak (kWh)	KWh/day
11/5/02 to 12/5/02	125,920	13,895.37	53,600	94,160	4,062
12/6/02 to 01/6/03	147,760	16,325.37	43,550	76,505	4,618
1/7/03 to 2/4/03	127,040	14,216.37	50,480	76,560	4,381
2/5/03 to 3/6/03	126,800	11,361.29	49,120	77,680	4,227

3.4 Fortuna's Energy Budget

The average annual electricity usage at the Fortuna facility is 1.5 million kWh/year with an average annual cost of $186,013.50. With a 10-20% reduction in energy usage the facility will save $1550.11 to $3100.22 per month, reducing the overall cost of operation to $14,000.00-$12,400.90 per month. The current energy usage will be reduced by 408 – 817 kWh per day. This results in an annual savings of approximately $20,000 to $40,000.

The Fortuna facility is managing the load properly by shifting the bulk of the energy usage from the peak periods to the off-peak periods. The Fortuna facility can achieve energy savings by additional load shifting, equipment upgrades, system modifications, cogeneration and other new and innovative technologies, which will be discussed in the following sections.

4 Fortuna's Areas of Concern

4.1 The Activated Sludge Process

The activated sludge process has been identified as the number one energy consumer in the wastewater treatment process. The Fortuna wastewater treatment facility uses the majority of the energy required to operate the facility during the activated sludge process. The primary component of the activated sludge process is aeration. Aeration is the most energy intensive mechanical process of all wastewater processes. Therefore, activated sludge is the largest energy consuming process simply due to aeration.

The aeration process introduces air or oxygen into the wastewater to promote aerobic biological activity, which degrades the organic matter in the waste stream (USEPA 1999, WPCF 1981). The biological material produced is separated from the effluent in the secondary clarifiers. The material that settles out is either wasted or returned to the process where it is mixed with incoming wastewater. The more oxygen transferred to the wastewater the higher the dissolved oxygen concentration. Aeration serves two purposes, first is to deliver oxygen to the water and second to mix the wastewater, which will keep the microorganisms in suspension. The amount of air supplied to reduce the organic material is usually sufficient to satisfy mixing requirements (ERPI 1998).

The air or oxygen can be delivered to the wastewater stream either mechanically or through a diffused system, which uses different types of diffusers (fine bubble or coarse bubble). Some of the diffusers are more efficient at transferring the air or oxygen to the water. The Fortuna facility uses a course bubble diffuser.

These aeration systems can account for 60% of the facilities energy requirements. This makes aeration an excellent target for energy reduction strategies. In order to optimize the aeration process a detailed system evaluation is required. Basin geometry, oxygen transfer method, wastewater characteristics, biological loading, equipment type and size, aeration controls methods and maintenance should all be evaluated carefully in order to determine the tradeoffs associated with energy reduction.

The equipment used in the aeration process are referred to as blowers. The blowers compress and distribute air to the aeration basin at pressures up to 15 psi. The City recently purchased two 60 horsepower blowers, which are now in operation. The older 100 horsepower blowers will remain as backups during extreme events.

4.2 Preliminary Treatment

Preliminary treatment consists of screening, grinding and grit removal. The primary objective of the preliminary treatment process is to protect plant equipment from large objects and debris. Only a small portion of the plants energy requirement s is used in the preliminary treatment process; however, it is still feasible to reduce energy by redesigning the inlet works of the wastewater treatment plant. Fortuna's preliminary treatment system is not working correctly and could be causing some increased energy usage later in the process. This system is essential to the success and efficiency of the process. This is an area that must be improved to conserve energy later in the process.

4.3 Primary Treatment

Primary treatment or primary sedimentation is where a significant portion of settleable solids and biochemical oxygen demand will be removed. After evaluating a year's worth environmental data, inconsistencies in the effectiveness of the primary clarifiers were observed. The clarifiers are failing to remove the proper amount of solids and BOD from the wastewater stream. This leaves the aeration system to remove all of the remaining BOD and the secondary clarifiers to remove all of the extra solids. It is predicted that by improving the removal efficiencies of the primary clarifiers a significant cost savings for energy use would result. This has been identified as an area that can be easily and fairly inexpensively upgraded to improve the overall treatment and energy efficiency.

4.4 Sludge Stabilization

The sludge is stabilized by an aerobic process, which also uses aeration to transfer oxygen to the sludge. Once the sludge is stabilized it is pumped into drying beds where it remains until completely composted. The problem associated with the aerobic process is that aeration is required and it has been established previously that aeration is extremely energy intensive. The stabilized sludge product is pumped to drying beds where it is composted for use as a soil amendment; however, the drying beds are subject anaerobic conditions, which result in a very odiferous sludge product. This odor becomes a nuisance to the community.

5 The proposed upgrade

The Fortuna wastewater treatment plant will be upgraded within the next few years. Ecologic is the consulting firm that is currently working in conjunction with the City of Fortuna on the proposed upgrade. The consulting company has been given a laundry list of problems that need to be addressed in the upgrade. Unfortunately due to financial constraints the primary problems that will be addressed include:

- Odor
- Preliminary treatment
- Sludge Storage

The primary goal of the upgrade is to reduce odor associated with the current process. The existing aerobic sludge stabilization system will be replaced with an anaerobic system. A byproduct of the anaerobic system is methane, which will be burned in a boiler that will heat the incoming wastewater stream to approximately 93-97 degrees Fahrenheit. The heated wastewater is required for the anaerobic process to work properly. The remaining gas will be "flared" off to the atmosphere. The anaerobic system will also mitigate the problems associated with sludge storage.

As discussed previously the preliminary treatment system is not in working condition. Improving this phase of the wastewater treatment process will decrease equipment breakdown and failure. The efficiency of substrate removal may also be improved later in the process.

6 Energy Efficient Alternatives

With rising energy prices and stricter discharge requirements energy conservation is the primary management tactic to reduce operating costs while meeting budgetary constraints. Energy efficiency not only helps save money but also reduces pollution. Several energy efficient technologies will be discussed in the following sections. These technologies only represent a fraction of what is available however; these are most applicable to the Fortuna facility.

6.1 Variable Frequency Drives

Variable frequency drives are electronic device used to control motor and equipment speed. These electronic devices simplify speed control systems. Variable speed drives have many benefits, which include reduced energy usage and improved process control. The systems can be used in conjunction with motors of any size including pumps used in the wastewater treatment process. VFD's consist of three main parts; the rectifier, the regulator, and the inverter. The Rectifier converts alternating current (ac) into direct current (dc). Then the Inverter switches the rectified direct current to alternating current, which results in a variable alternating current frequency. The regulator controls the rectifier and the inverter in order to maintain the proper frequency and voltage. There are three types of variable frequency drives, these include (EPRI 1998):

- Pulse Width Module Inverters (PWM)
- Voltage Source Inverters (VSI)
- Current Source Inverters (CSI)

The PWM is the most common variable frequency drive and is typically used in applications where motors are less than 100 horsepower (EPRI 1998).

6.2 Energy Efficient Motors

Energy efficient motors or high efficiency motors consume less energy and can lead to a significant decrease in operational costs as compared to standard motors. The high efficiency motors typically cost 10 to 30 percent more than the standard motors; however, the high efficiency systems are constructed of better materials and have longer life spans. These motors are traditionally more durable, generate less noise, and have an improved tolerance to over-voltage. There are many benefits to using energy efficient motors, cost just being one of them (EPRI 1998).

In the past several decades the traditional methodology for designing wastewater treatment facilities has been to over size everything. Commonly motors are operating at 70-80% of the estimated capacity. These conditions lead to excessive energy usage. Motors are most efficient at certain operating points. If the system is not operated in that region than the result is an inefficient motor. Critical to energy conservation is properly sized pumps, fans, motors and compressors. Proper maintenance of motors is also critical to maintaining the optimal operating efficiency (EPRI 1998).

6.3 SCADA or Other Data Monitoring Systems

The Supervisory Control and Data Acquisition System (SCADA) is a computer operating system that automatically monitors and controls wastewater treatment operations. There are many different types of computer control systems; however, in this research only the SCADA system will be examined. There are a variety of benefits associated with the SCADA system; energy cost savings (through process monitoring), reduced operating and maintenance costs, better process control and more accurate data collection (EPRI 1998).

6.4 Pump Modification

Pumps are the predominate type of equipment in wastewater treatment systems. Therefore, optimizing pump efficiencies is essential for energy conservation. Pumps can operate inefficient for a number of reasons. Typically, pumps are oversized for the system and the result is low efficiency. Other problems can also affect the efficiency of pumps these include (EPRI 1998):

- Low quality parts
- Improper pump use
- Worn out parts
- Changes in operating conditions

Pump tests can be performed to determine if the operating parameters of the pump have changed from the manufacturer specified operating point. During the pump test data for the following parameters must be collected, flow, discharge pressure, suction pressure, temperature and amps. The data is then graphed and compared to the manufacturer specified conditions. When a significant discrepancy exists the pump can be corrected by changing the impeller, pump or system head. Optimizing pumps can accomplished in several different ways (EPRI 1998):

- Reduce impeller size
- Reduce discharge head
- Reduce the size of the pump to operate closer to optimal efficiency (have a backup system for excessive events)
- Add a variable frequency drive
- Increase suction head
- Proper maintenance and maintenance records

6.5 Cogeneration

Cogeneration is becoming essential in the survival of many wastewater treatment facilities. Cogeneration is a save, effective, reliable and cost effective method of power generation that has been is use for many decades. Cogeneration systems in wastewater treatment facilities use anaerobic digester gas (methane) to power prime movers, which generate electricity. A significant reduction in electricity usage can be achieved through cogeneration. Decreasing the amount of electricity required to operate a facility ultimately leads to a substantial cost reduction (EPRI 1998, WPCF 1981, Owen 1982). Cogeneration systems are complex and can be difficult to understand. The primary thing to remember is that waste gas generated during the anaerobic sludge stabilization process is used to power a prime mover, which in turn runs a generator that generates electricity.

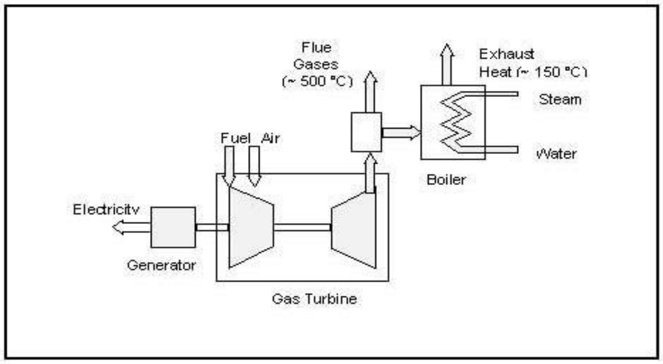

Figure 1 Generic cogeneration system diagram

6.5.1 Heat Recovery

During cogeneration only a portion of the gas is convert to electricity the other portion is lost throughout the process as heat. Some of the heat that is generated during cogeneration can be captured and reused. Heat can be recaptured with heat exchangers or routed through a building and used for space heating. Heat recovery is essential to the success of cogeneration systems in wastewater treatment. The excess heat can be heat exchanged with incoming effluent to preheat the effluent as it enters the anaerobic digester. Figure 1, shows what typical cogeneration process would look like at a wastewater treatment facility (WPCF 1981).

6.5.2 Micro turbines

Micro turbines are used as prime movers in the cogeneration process. These systems are adaptable low emission power generation systems, which are made small enough that even a small wastewater treatment facility could benefit (. The turbine can operate independently or through a grid connection. The maintenance required for a micro-turbine is minimal compared to a traditional gas turbine. Air emission Equipment will be required to stripe the methane gas of sulfur

Figure 2 Capstone micro gas turbine

compounds and water vapor prior to being used in the micro turbine. The waste gas is high in hydrogen sulfide, sulfur dioxide and water vapor. Therefore, additional capitol costs are required for the pollution equipment.

6.5.3 Prime movers

Prime movers are internal combustion engines and gas turbines. Gas turbines are primarily used in larger treatment facilities; however, micro-gas turbines are becoming cost effective and viable. Any engine can be converted into a prime mover with an experienced mechanic. There are no guarantees that the engine will run efficiently but if money is an issue than some electricity is better than none (WPCF 1981).

6.5.4 Fuel cells

Fuel cells technology has been moving forward rapidly and picking up momentum along the way. There are currently three main types of fuels cells that are showing potential for success, these include:

- Molten Carbonate
- PEM
- Phosphoric Acid

Currently molten carbonate and phosphoric acid fuel cells are being used as prime movers for cogeneration at wastewater treatment facilities. Fuel cells are significantly more efficient than traditional prime movers and the air emissions for using the waste-gas is very low in comparison. Fuel cells are still extremely expensive and not a potential option for the Fortuna facility. The technology has come along way and will in the future be an option for cogeneration. There are issues associated with fuel cell use in waste-gas cogeneration. Waste-gas contains a significant amount of hydrogen sulfide and trace metals, which can result in some operational problems for fuel cells. Additional capitol costs for gas striping equipment will be required to operate fuels cells with waste gas (USFCC 2002).

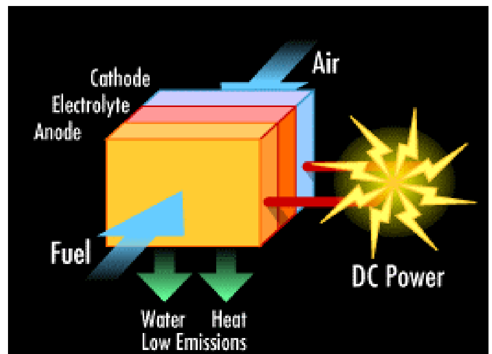

Figure 3 Molten Carbonate fuel cell

PEM fuel cells use pure hydrogen to generate electricity. The resulting emissions are carbon dioxide and water. The PEM fuel cell could potentially be used to generate electricity at a wastewater treatment facility by the following scenarios:

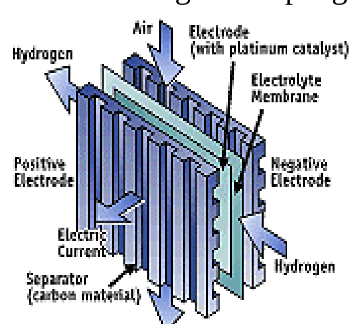

Figure 4 PEM fuel cell

- Methane reformation of waste-gas (The hydrogen will need to be purified)
- Two-phase anaerobic separation where the first phase liberates hydrogen and the second phase liberates methane.

Neither of these technologies has advanced far enough along to become a reality but the future looks bright.

6.6 Retrofitting Aeration Systems

Aeration is the primary source of energy consumption at wastewater treatment facilities. Aeration devices consume 60-85% of the electricity required for the wastewater treatment facility. Aeration systems can become more efficient by implementation of the following (EPRI 1998):

- Fine bubble diffusers in the aeration basin (improves oxygen transfer efficiency)
- Upgrade to energy efficient blowers and size appropriately
- Automated dissolved oxygen control
- Oxic / Anoxic zones in basin

Upgrading Fortuna's aeration system would be the best approach for energy reduction. A formal energy audit of the process is required to determine optimal operating conditions. The suggestions above are all feasible for the Fortuna facility; however, a detailed cost analysis is necessary to determine which alternative would be the optimal option.

6.7 Managing plant loading

The key element in managing the plant load is to optimize the primary clarifiers. The primary clarifiers can remove 50-70% of the suspended solids and 25-45% of the BOD (EPRI 1998). Early removal of substrate improves energy efficiency later in the process. There are also chemical additives that can be placed into the primary clarifiers to increase the removal of the solids and BOD.

Flow equalization is another method of load shifting. The objective is to shift the energy requirement from peak to off-peak hours. This can be accomplished by using holding / oxidation ponds as storage during the peak hours. Wastewater flows will be slowed during peak hours and increased during off-peak periods (EPRI 1998).

7 Cost and Benefits of Energy Efficiency

Energy conservation in wastewater treatment is essential to promote environmental stewardship for future generations. The benefits of energy conservation significantly out weighs the costs. Air pollution and greens house gas emissions will be reduced and water quality will be improved. The Fortuna facility is an excellent location to promote energy efficient alternatives. The facility is small and the community is supportive. Typically, energy conservation measures are incorporated at large treatment facilities because the payback is quick and economies of scale exist. Fortuna does not have this same advantage; however, small communities are the most in need of cost savings.

It is predicted that the Fortuna facility can reduce there operating costs by $40,000 per year with simple modifications to the primary clarifiers, preliminary treatment system and the aeration system. The possibility exist that even more savings are possible with the addition of an anaerobic system. The predicted payback period for the simple projects would be less than 5 years, with a predicted life span of twenty years that results in a significant savings to the City of Fortuna.

8 Environmental Benefits of Energy Efficiency

There are many benefits to energy efficiency. Typically, energy conservation measures are quantified in terms of cost savings. However, there is much more to energy conservation than just saving money. Electricity generation requires the burning of fossil fuels; coal, natural gas, and oil. In the United States, electricity generation accounts for more than 35% of the carbon dioxide emissions, 75% of the sulfur dioxide, and 38% of the nitrogen oxides (Arora et al., 1998). Carbon dioxide is a green house gas, which is contributing to global warming and major climatic change. Sulfur dioxide when combined with water vapor in the atmosphere forms acid rain. Nitrogen oxides contribute to smog and also combine with water vapor in the air to form acid rain. Every time a light is switched on, a power plant consumes fossil fuels to generate electricity. Conserving energy reduces the amount of fossil fuels that are burned, which results in a decrease in air pollutants that cause global warming and acid rain (Arora et al., 1998).

9 Financing Energy Efficient Upgrades

There are many incentive programs that promote energy efficient upgrades for municipal projects. The California energy commission gives low interest loan at 3.95% interest for energy efficiency improvement projects. These loans are available to Cities, public and non-profit schools, counties, hospitals and other public care institutions. Lower interest rates on these loans are obtainable if the project is completed within nine months (CEC 2002).

The California Energy Commission also sponsors two grants programs for water and wastewater energy efficiency projects. The demand reduction program is designed to promote load shifting and energy reduction during peak periods. The program offers $300/kw demand reduction during peak periods. The load-shedding program is designed to allow participants to retrofit pumping systems. The program is offering $200/kw demand ruction during peak hours. The requirements for the two programs include a minimum reduction in peak demand of 20 kW (CEC 2000). This is a significant reduction in demand during peak hours but it is attainable for the Fortuna facility.

The California wastewater treatment processs optimization program is administer through Quantum Consulting and partially funded by grants from the California Energy Commission. The program pays for energy saving process improvements and includes training of personnel and equipment.

Currently PG&E is not offering any energy incentive programs; however during the summer months they typically offer incentives for peak demand reduction. Other types of funding are also available through federal agencies.

10 Case Study: The City of Santa Rosa

The City of Santa Rosa's wastewater treatment plant in Laguna treats approximately 17.5 millions gallons per day of wastewater. The Laguna plant is a tertiary treatment facility that utilizes an activated sludge process coupled with an ultraviolet disinfections system. The aeration system consists of six 900 horsepower centrifugal fans. Two of the fans are used all of the time and the other four fans are primarily for backup. The facility also has a cogeneration system that powers two 900 horsepower lean burning engines (CEC 2002).

In 2000, the City of Santa Rosa began investigating energy efficient alternatives for the Laguna wastewater treatment facility. With the assistance of Provometrics, an energy consulting firm, secondary treatment was identified as an area of improvement. Secondary treatment consists of aeration blowers, which distribute oxygen to the wastewater stream. The current blowers were consuming approximately 7.6 million kWh/year, which cost $780,000 to operate. This was approximately 20% of power requirement of the entire facility (CEC 2002).

Provometrics used the SCADA system to collect data about the energy usage of the aeration blowers for an entire year. The SCADA system demonstrated that the overall energy efficiency of the blowers ranged from 34-54%. The lowest readings occurred when both blowers were in operation at the same time. The blowers should be about 65% efficient at full operating capacity. This opened the door for significant improvement in energy usage. The dissolved oxygen in the aeration basin was monitored and automatically controlled. If the dissolved oxygen dropped below the desired set point than the inlet valve would open allow more oxygen to be transferred to the basin. Butterfly values were found to be controlling inlet airflow on the fans; this resulted in decreased fan efficiency (Provometrics 2000).

The two fans were replaced with two new smaller, energy efficient fans. Four possible energy efficient alternatives were examined. The energy costs associated with each alternative were evaluated and the most cost effective energy efficient alternative was found to be, "two new 600 horsepower fans controlled by variable diffusers and inlet vanes" (CEC 2002).

10.1 Results

The Laguna facilities aeration fans were replaced by two smaller more efficient fans. The predicted energy savings is 4-million kWh/year, which results in an annual savings of $400,000. This reduces the energy consumption of the facility by 53%. The project was predicted to cost $1.5 million with a payback period of less than four years (CEC 2002).

11 The Next Step

The next phase of the research process would to conduct a full energy audit of the Fortuna facility and accurately determine how much electricity is required and where. A set of feasible alternatives can be developed from the data collected during the energy audit and the research presented in this document. A cost benefit analysis can then be performed on the alternatives in order to fully assess, which alternatives are optimal. The optimal energy efficient alternative can be presented to the City Council with various funding options. Ideally a grant to perform a series of energy efficient upgrades would greatly benefit the community.

12 Conclusions

The costs associated with energy consumption will continue to be a large portion of the City of Fortuna's wastewater treatment facility operational budget. With rising energy prices and increased population growth energy conservation will become essential to the success of a small treatment facility. Conserving energy is not only cost effective but is also reduces green house gases. That in it self should be enough to start conserving!

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